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30 May 1997

A Beach Probing System (BPS) for Determining Surf Zone Bathymetry, Currents, and Wave Heights from Measurements Offshore: Phase I - The Prototype Development and Capability Demonstration

Semi-Annual Report #2

Covering the Period 1 October 1996 Through 31 March 1997
For Contract N00014-95-C-0217

Prepared by
Joan Oltman-Shay
James A. Secan
Douglas C. Echert
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Prepared for
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Overview of the Report Organization

This report contains both a technical and financial accounting of the activities of the past six months for ONR Contract N00014-95-C-0217. A description of the technical activities can be found in section 1.0, organized by project task. The anticipated work for the next six months is outlined in section 2.0 followed by the financial report (section 3.0).

An integral component of the reporting is the documentation of the BPS hardware and software designs and operation plans (documents listed below). These are "living" documents in that they are undergoing modifications, additions, and enhancements during the life of the project. They are documented separately from this report and are referenced within where appropriate. Please note that asterisked volumes are not available at this date.

<u>List of BPS Documents</u>

BPS Software Documentation (NWRA-CR-R156)

Vol. 1. On-shore Software Design and Specification
Vol. 2. In-situ Software Design and Specification
*Vol. 3. Software Test System

***BPS Concept Testing Software Documentation (NWRA-CR-96-xxxx)**

Vol. 1 Concept-Testing Software Design and Specification
Vol. 2. Concept-Testing GUI Design and Specification

BPS Hardware Documentation (NWRA-CR-96-R161)

Vol. 1. Instrument Design and Specification
*Vol. 2. Field Deployment and Hardware Design and Specification

***BPS Concept of Field Operations Documentation (NWRA-CR-96-xxxx)**

Vol. 1. Field Campaign #1 – Concept of Operations
Vol. 2. Field Campaign #2 – Concept of Operations
Vol. 3. Field Campaign #3 – Concept of Operations

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1.0 WORK PERFORMED 1 OCTOBER 1996 - 30 MARCH 1997

1.1 Task 1: Concepts and Algorithm Development

1.1.1 Overview

In the October 1996 Semi-Annual Report we listed the Task 1 milestones and objectives to be met by the end of the six month reporting period. These are listed again below.

1) Code and test the data quality control algorithms for the Sensor Package field test;
2) Design the data quality control algorithms for Field Campaign #1;
3) Design the inversion method (ver. 1.0);
4) Code and test the Concept-Testing GUI;
5) Update the BPS Concept-Testing Software Documentation;
6) Report on the status of the stability, sensitivity, and capability testing of the inversion method.

Following the October 1996 report, an Advisory Panel meeting was held (see section 1.5.2 of this report). As a result of discussions during that meeting, new objectives were assigned to Task 1 and timelines were modified. The most significant changes are noted below.

1) Shorten the time-line on the inverse method design and testing to aid in the programmatic assessment of the value of field experiments to test the inverse concept;
2) Explore alternative data analysis and inverse methods of the infragravity wave data;
3) Begin the process of defining a criterion of success for the BPS project;
4) Consider modifying several points of the BPS Concept of Operations.

Below are the status of these efforts with a brief outline of the results or a direction to the locations in this report with more detailed discussions (sections 1.1.2 - 1.1.4).

1) Code and test the data quality control (QC) algorithms for the Sensor Package field test.
   Done. The base codes were handed over to Task 3 for integration into the BPS Onshore Processing Software.
2) Design the data quality control algorithms for Field Campaign #1.
   Partly done. Algorithms have been passed on to Task 3. However, Task 1 is still needed for consultation on a design layout for the user QC interface and the QC threshold values for alerting the operator. Defining the user interface and the threshold values will start Fall 1997.
3) Design the inversion method (ver. 1.0).
   Done. Our first approach (ver. 1.0) to this problem is described in detail in section 1.1.3 along with some initial results from the uniqueness and stability testing.
4) Code and test the Concept-Testing GUI.
   Partially done. Perl scripts have been designed, coded, and tested for automation of the processing of field data, simulation of infragravity wave data, and the building of processed data files for reference by the inverse model. In addition, the infragravity wave

codes were modified so that all codes now read from a common input file of parameters. These two steps are basic building blocks of the Concept-Testing GUI.

5) Update the BPS Concept-Testing Software Documentation.
Delayed until the hiring of additional support staff. We filled the position of Support Scientist on 1 April 97. This person's first task is updating this documentation.
6) Report on the status of the stability, sensitivity, and capability testing of the inversion method.
Done. See section 1.1.3 of this report.
7) Shorten the time-line on the inverse method design and testing to aid in the programmatic assessment of the value of field experiments to test the inverse concept.
Ongoing. Section 1.1.3 of this report contains preliminary results on the capability of the template-matching technique for estimation of a plane beach approximation to the true depth profile and for the infragravity information content in a perturbation about a plane beach approximation.
8) Explore alternative data analysis and inverse methods of the infragravity wave data.
Delayed until the present data analysis and inverse approach (ver. 1.0) is explored.
9) Begin defining a criterion of success for the BPS project to foster further discussion with the Advisory Panel.
Begun. A table of the attributes of BPS and other nearshore environmental surveillance systems is presented in section 1.1.4, along with a study of the expected error in beach slope using SEAL teams for hydrographic surveying.
10) Consider modifying several points in the BPS Concept of Operations.
Done. A Concept of BPS Operations is outlined, for the first time, in section 1.1.2.

1.1.2 Concept of Operations for the BPS Station

In this section, we begin the documentation of a general Concept of Operations (ConOps) for the BPS Station. Each experiment has its specific ConOps (e.g., Field Campaign #1, section 1.2.3 of this report and section 1.2.3 of the October 1996 Semi-annual Report). However, there are general operational designs and procedures that are common to all experiments and to which the BPS Station has been designed. Provided below is version 1.0 of the BPS ConOps document. It is not complete; the content is expected to grow in detail and evolve over the life of the project.

A schematic of a Field Campaign is shown in Figure 1.1.2-1. This figure shows two BPS Arrays offshore of the breakers with concomitant Sensor Packages (filled circles) aligned parallel to shore, a Junction Box (J8) for each array, a cross-shore array of Sensor Packages in the surf zone, and a trailer housing the Onshore Array Controllers and Processors. Each BPS Array is part of a BPS Station.

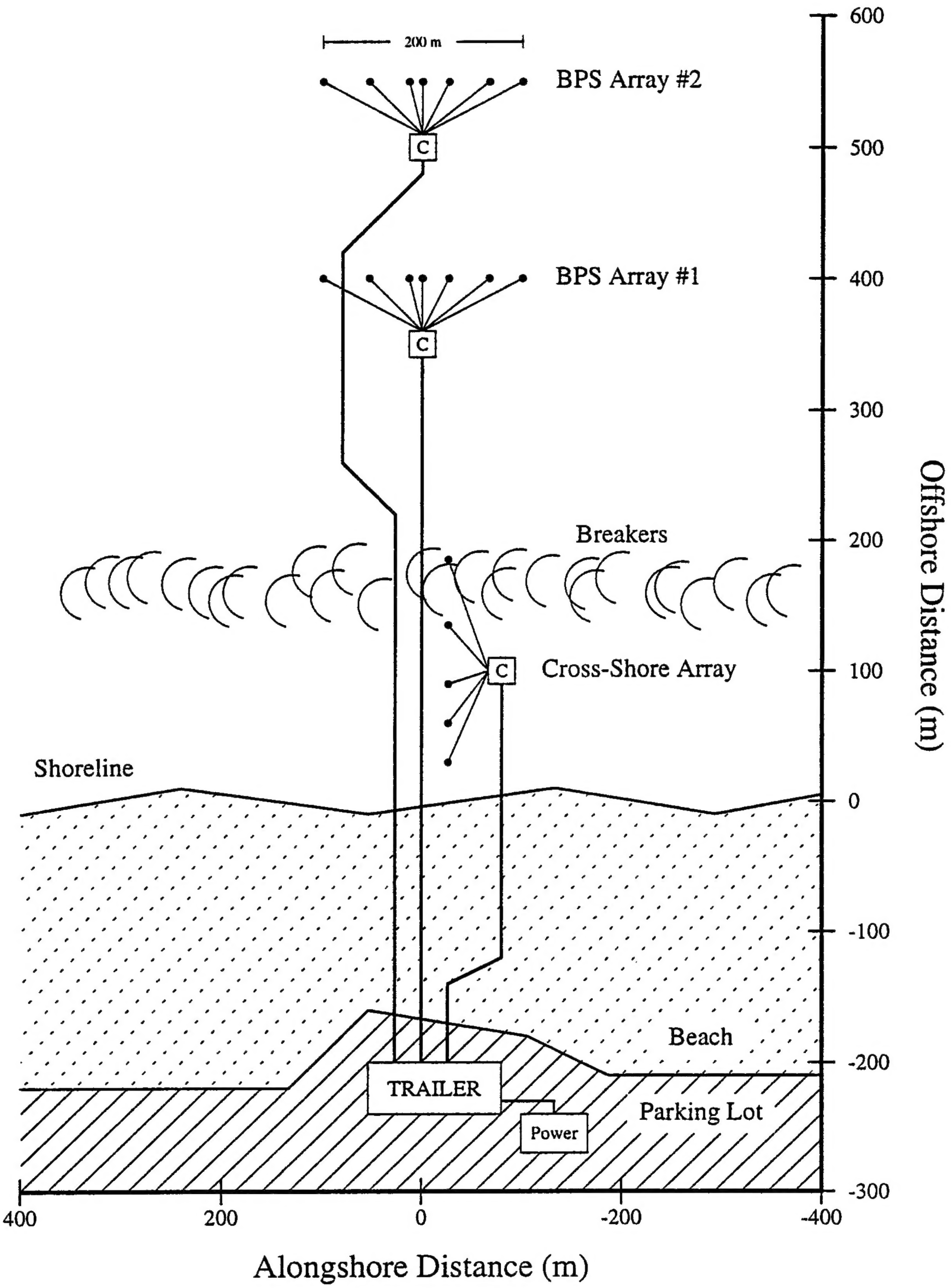


Figure 1.1.2-1. Plan view of a BPS Field Campaign with two BPS Stations deployed offshore at the breakers and a cross-shore array of Sensor Packages placed in the surf zone.

1.1.2.1 Station Definition

A BPS Station consists of:

- 1 - In-situ BPS Array of Sensor Packages;
- 1 - In-situ Junction Box;
- 1 - Onshore Array Controller Package;
- 1 - Onshore Processor.

1.1.2.2 Array Definition

Each BPS Array consists of 5 to 7 Sensor Packages.

Each Sensor Package contains:

- 1 - 3-axis current meter;
- 1 - pressure sensor ;
- 1 - compass and inclinometer;
- 1 - data logger/controller;
- clock;
- batteries;
- data storage;
- 3 - external auxiliary ports for:
  - ⇒ temperature/conductivity gauge;
  - ⇒ altimeter;
  - ⇒ other.

1.1.2.3 Data Acquisition

- Each Sensor Package transmits data to the in situ Junction Box over an 8-ply SO cable;
- The Junction Box combines the cables from each of the Sensor Packages into a single 32-ply cable (16- or 36-ply, TBD), to the Onshore Array Controller;
- The Sensor Packages are powered from shore through the data transmission cables;
- Data Sample Rate = 2Hz;
- Data Sample Blocks = 17.066 min (2**11 data pts).
- Each Sensor Package has an internal clock that is synchronized to a common GPS clock in the Onshore Array Controller;
- If communication to shore is interrupted, each Sensor Package automatically switches to battery power;
- The internal Sensor Package clock has a maximum drift of 0.05 msec over 17.066 min and 13 msec over 3 days (the maximum life of the batteries).

1.1.2.4 Array Deployment Configuration and Range of Depths

- BPS Arrays consists of 5 to 7 Sensor Packages aligned parallel to shore.
- The nominal array length (end to end) is 200m;
- Distance between sensor packages varies from 5 to 100m;
- Depths of deployment can range from 1 to 15m.

1.1.2.5 Onshore Data Processing and Analysis

The following steps are taken in near-real time:

- Archive raw data;
- Convert data to physical units and local coordinates;
- Archive transformed data;
- Perform data quality control with interactive BPS Array Status Display;
- Spectral analysis of infragravity waves;
- Spectral analysis of wind waves;
- Analysis of surf zone environment:
  - ⇒ depth profile;
  - ⇒ breaker heights, location, and type;
  - ⇒ surf zone width;
  - ⇒ longshore currents.

1.1.2.6 Supplemental Data Collection and Analysis

- Nearshore Bathymetry;
- Wave heights and currents across the surf zone (measured by cross-shore array of Sensor Packages).

1.1.3 The Inverse Method (ver. 1.0)

(Contributing authors: Uday Putrevu and Robert Fraser)

1.1.3.1 Overview

The objective of the BPS inverse problem is to extract depth profile information from measurements of wavenumber-frequency (k-f) spectra of infragravity edge waves. In our first approach (version 1.0), we break the problem up into two parts: 1) estimation of the slope of a planar depth profile approximation to the true depth profile, followed by 2) estimation of perturbations about that planar depth profile.

We are considering three approaches for estimating the slope of a plane beach approximation:

1) A "Template-Matching Technique" (TMT) that matches measured k-f spectra against a library of true k-f spectra of different beach slopes and offshore measurement locations.

2) A "Radial-Energy Technique" that transposes the k-f spectra to f^2-k space and adds up energy that falls on radial lines that pass through f=k=0. A plot of energy versus angle of the radial line is then used to identify the plane beach slope. This technique was suggested by Rob Holman at the 14 Nov 96 Advisory Panel Meeting.

3) A "Time-Travel Technique" that estimates a nominal beach slope from the time lag between incident and reflected infragravity waves and knowledge of the local depth and integrated (cross-shore) shallow water phase speed. An attractive feature of this technique is that it would not require a phase array of sensors. One Sensor Package (current meter and pressure sensor) would suffice. However, if there were no data from a phase array, it would not be

possible to follow this analysis with one that extracts nonplanar depth profile features. Nonetheless, some shoreline features could possibly be deduced from differences in measurements acquired at low and high tide. This technique was suggested by Rob Holman at the 14 Nov 96 Advisory Panel Meeting. (An additional interesting application of this technique would be to examine alongshore bathymetric inhomogeneity of the depth profile across the array length).

We have thus far only examined the TMT (Template-Matching Technique). A progress report on our study of the uniqueness and repeatability of the plane beach solution can be found in section 1.1.3.2.

The second step of the BPS Inverse Method (ver. 1.0) is to estimate perturbations about the plane beach approximation (obtained from the first step). Over the past six months we have examined the forward problem where we have applied a perturbation expansion to the edge wave equations to obtain zeroth- and first-order edge wave solutions. The zeroth-order depth profile that defines the zeroth-order edge wave solutions is arbitrary, but could be a plane beach; the first-order problem would then be perturbations about the plane beach slope.

The results are very promising for the inverse problem. The salient points are listed below.

1) Surprisingly, at a given wavenumber, the k-f relationship and the cross-shore structure of the higher mode edge waves are more influenced by shoreline features than the lower mode edge waves. This means that even though higher mode edge waves travel farther offshore than lower modes, and are responding to a larger cross-shore integration of the depth profile, they are nonetheless more sensitive to shoreline features. This observation is relevant to the application of the BPS concept to Naval operations. It suggests that there is information in the edge wave field about shoreline features farther offshore than previously thought.

2) The spatial structure of the edge wave is influenced more by shoreline features than is the k-f dispersion relationship. This implies that we should try to utilize as much information as possible about the cross-shore variance structure observed in the k-f spectra for the inverse problem. Cross-shore variance structure information could be obtained by identifying frequencies of mode jumping in the k-f spectra or by including measured variance along with the k,f peak location data.

3) The first-order corrections to the edge wave solution (from a zeroth-order plane-beach solution) can be obtained from the cross-shore integral of an "influence" function multiplied by the first-order perturbations to the depth profile. The influence function for the dispersion relation is different from the influence function for the cross-shore variance structure. In addition, there is a different influence function for each edge wave mode and the influence functions scale with wavenumber (or frequency).

   The influence function for the first-order correction to the dispersion relation is positive everywhere. This means that the bottom perturbation that will yield the largest perturbation to the edge wave dispersion solution is one that has the same sign everywhere. The implication for the inverse problem is that the effect of depth profile features such as

foreshore steepening will be seen in the observations of the first-order corrections to the edge wave dispersion, but the effect of bars and troughs may not be seen or may be misinterpreted as a foreshore steepening.

However, the influence functions for the cross-shore elevation and velocity structure of the edge waves have both positive and negative values. Therefore, if cross-shore structure information is included in the inversion, then features such as bars and troughs may not be misinterpreted as foreshore steepening. These features may likely have a unique signature in the k-f spectrum.

The above summarizes points in our edge wave perturbation study that are relevant to the BPS inverse problem. These results will help in the design of the inverse model: we have learned of the importance of using observations of both the cross-shore variance structure and dispersion relation in the inversion approach. And, these results are encouraging: the infragravity waves carry information about shoreline features farther offshore than previously thought and we are, for the first time, considering the possibility that the BPS inverse technique may be able to pick up features such as bars and troughs! For a more detailed presentation of our work, a copy of a manuscript that has been submitted to *Physics of Fluids* can be found in Appendix A.

1.1.3.2 The Template-Matching Technique (TMT) Uniqueness and Stability

The Template-Matching Technique, as its name implies, matches measured k-f spectral parameters (i.e., data matrices) against a library of true k-f spectral parameters (i.e., test templates). The test templates in a given library have a common user-defined edge wave field of modes with concomitant amplitudes. The templates differ in the assumed beach slope and offshore observation location. The k-f spectral parameters that define the test template are obtained from the analytic edge wave solutions for a plane-sloped beach. Both edge wave dispersion and cross-shore variance structure information are used to define the test template. The template is a 2-D (k-f) matrix of numbers. The k,f matrix element location that satisfies the edge wave dispersion solution is given a value of one. All other elements are zero. The cross-shore variance structure is included by filtering out edge wave mode dispersion solutions (zeroing matrix element values) when the mode variance is too weak to be observed; this is based on our experience with the behavior of our k-f spectral analysis tools and array geometrys. For the test template, we are presently setting the k,f matrix element of an edge wave mode to zero if the relative alongshore velocity variance of that mode is less than 0.9 times the mode with maximum velocity variance at the same frequency, f, and alongshore direction. The optimal method of mimicking the filtering of edge wave modes as observed by limited, offshore phase arrays and spectral analysis methods will be more closely studied at a later date. An example test template is shown in Figure 1.1.3-1.

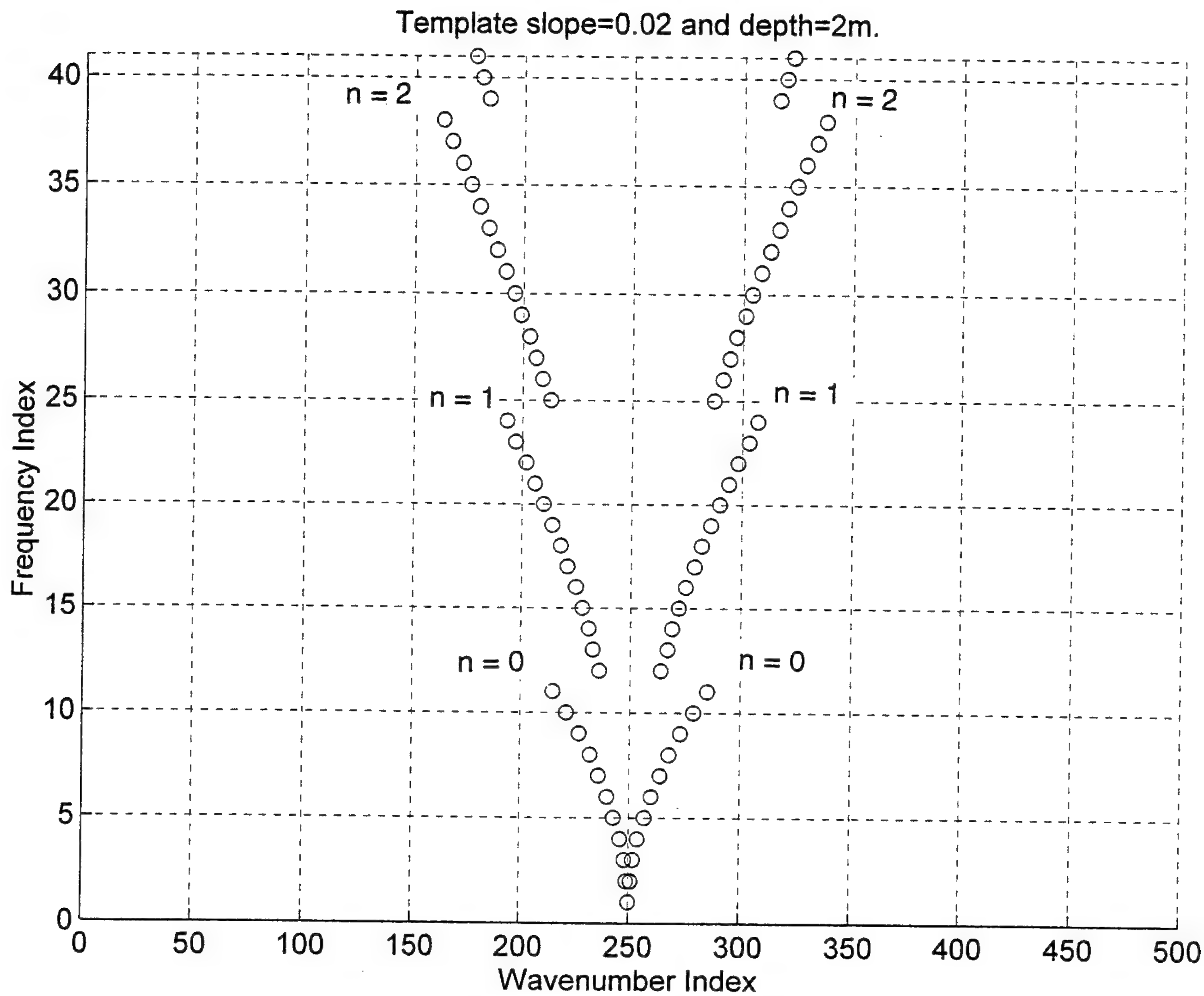


Figure 1.1.3-1. Example test template (beach slope = 0.02, observation depth = 2m). The circles identify the location of ones in the 500 by 41 (k by f) matrix. The diameter of the circles does not represent the size of the matrix. In physical units, each matrix element of the test templates used herein defines a $0.0001 m^{-1}$ by 0.00098 Hz spectral bin.

1.1.3.2.1. Test Template Library

For the tests presented in this report, test templates were generated for an edge wave field of 11 modes (0 through 10), with equal shoreline elevation amplitude. The library represents this edge wave field for beaches with slopes ranging from 0.01 to 0.10 in 0.005 increments and for observation depths of 1m to 10m, in 0.5m increments.

Our first test of the TMT was designed to address uniqueness of the solution. We were concerned that a test template for one beach slope and observation depth may look similar to a template for another beach slope and observation depth. To examine this, we matched each test template against the library of test templates. The matching algorithm yields a score that, in this case, is a matrix multiplication of a test template against each template in the library.

The highest score identifies the library template with the best match and provides a concomitant estimated beach slope and measurement depth.

We found that each test template was unique. This was encouraging. However, the matching of some templates in the library resulted in scores well above the background scores (but still well below the high score for the true match). This relationship arose because library templates with slopes that are 2n+1 multiples of the true slope (i.e., factors of 3,5,7, etc.) have similar configurations. For example, Fig. 1.1.3-2 shows the match for the template with slope 0.02 and depth 2m. The highest score is clearly for a library template with slope 0.02 and depth 2m, but we can also see spikes for library templates with slopes of 0.06 and 0.10 (3 and 5 times 0.02). The similarity of the template for slopes of 0.02 and 0.06 can be seen by comparing Figs. 1.1.3-1 and 1.1.3-3. Specifically, the shape of mode zero (n=0) in Figure 1.1.3-3 is the same as the shape of mode one (n=1) in Figure 1.1.3-1. This similarity is inevitable because of the basic dispersion relationship, and will pose a potential problem for any method used to identify beach slope solely from the dispersion measurements. This point is also relevant to the proposed "Radial-Energy Technique" for estimating plane beach slopes (section 1.1.3). We next explored the consequences of applying a wavenumber bandwidth about the k,f dispersion value of the test template. Some bandwidth is necessary to be able to match noisy data matrices, obtained from field observations, with the library of templates. To simulate the typical wavenumber bandwidth of field data, we applied a Gaussian spread in wavenumber to the distribution of numerical values in the matrix elements of the test template, the library of test templates was unchanged. We chose a 0.002 m^{-1} half-power bandwidth for the spread (this is commonly observed in field data). The difference between the score values for different matches was expectedly reduced. However, the uniqueness with this accurate (noise-free k,f values) but distributed (wavenumber bandwidth greater than the matrix element width) test template was maintained (Figure 1.1.3-4).

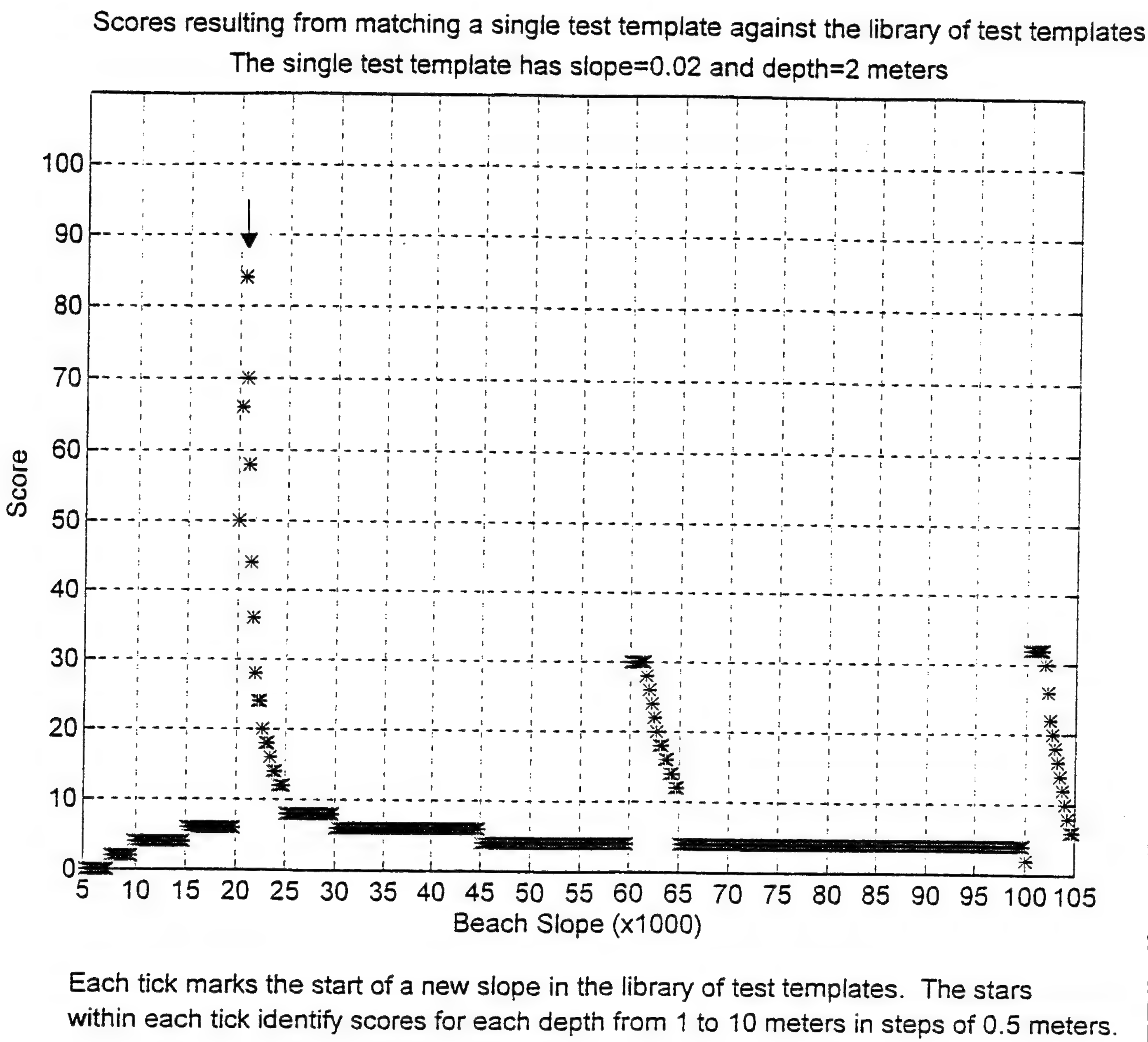


Figure 1.1.3-2. Template matching scores for a test template (0.02 slope and 2m observation depth) against the library of templates. Noise has <u>not</u> been added to this test template. The wavenumber bandwidth is equal to the matrix element width ($0.0001 m^{-1}$). The down arrow identifies the correct match and, encouragingly, also the highest score. Note the resonances at slopes equal to (2n+1)(0.02).

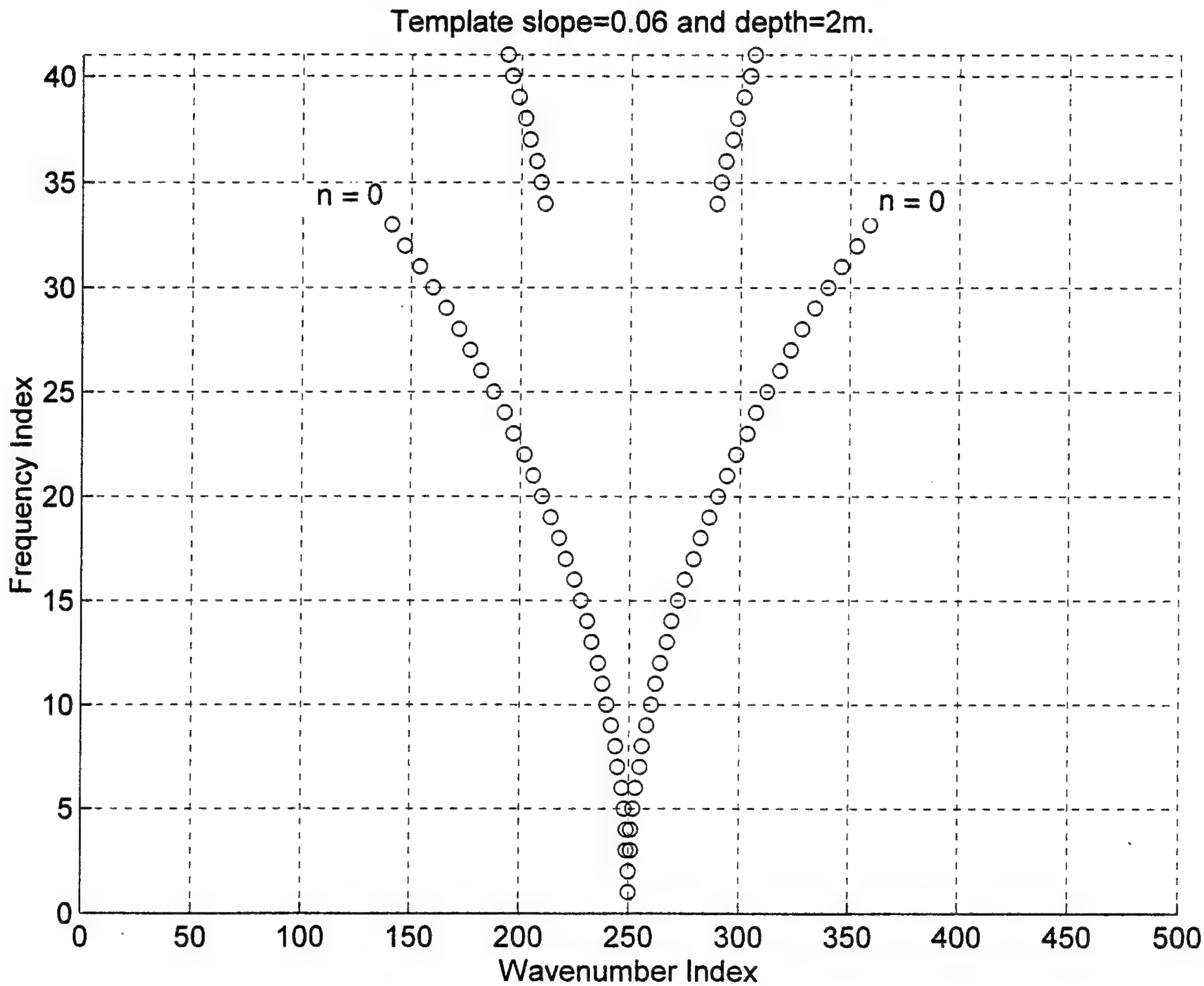
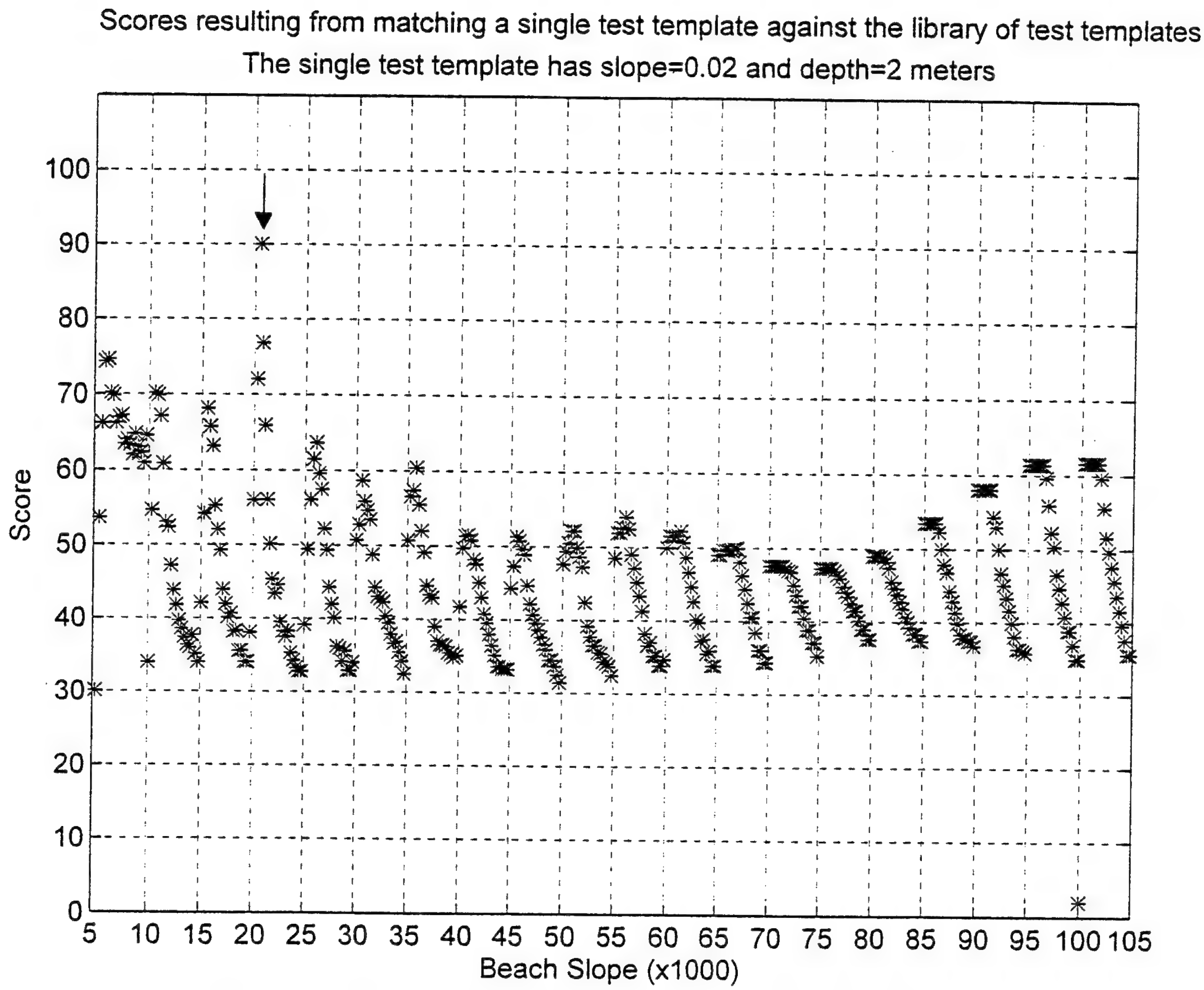


Figure 1.1.3-3. Example test template (beach slope = 0.06, observation depth = 2m).



Each tick marks the start of a new slope in the library of test templates. The stars within each tick identify scores for each depth from 1 to 10 meters in steps of 0.5 meters.

Figure 1.1.3-4. Template matching scores for a test template (0.02 slope and 2m observation depth) against the library of templates. The test template is noise free (k,y values), but has a wavenumber bandwidth spread of $0.002m^{-1}$, greater than matrix element width ($0.0001m^{-1}$). The down arrow identifies the correct match and, encouragingly, also the highest score. Note the resonances are not as distinguishable as in Figure 1.1.3-2; they are partially masked by the raised noise floor.

1.1.3.2.2. Simulated Data Matrices with Noise

Having established uniqueness of the templates in the template testing library, we next explored the matching of data matrices generated from field observations of the k-f infragravity spectra. To do this, we imitated field observations by simulating stochastic realizations of data matrices as follows:

1) Design a true k-f spectrum by defining the planar beach slope (variable, 0.01 to 0.10), the offshore measurement location (variable, 2 to 10m), the number of energetic edge wave modes (11), the shoreline elevation amplitude of each of the edge wave modes (1cm), and their half-power wavenumber bandwidth ($0.002m^{-1}$).
2) Build a cross-spectral data matrix by defining the array geometry (2-3-1-7 lag unit separation, 5 elements, minimum lag = 20m), broad-band noise level (NSR = 0.05), and stochastic noise level (DOF = 48, Δf = 0.0098Hz).
3) Pass the simulated cross-spectral data matrix through the high-resolution wavenumber estimator (Iterative Maximum Likelihood Estimator, IMLE), the peak-picker algorithm, and the data matrix generator.

Figures 1.1.3-5, -6, and -7 are simulated stochastic realizations of k-f spectra for beaches with slopes of 0.02, 0.05, and 0.08, respectively. Each spectrum simulates an observation location of 5m depth. The rectangular boxes in these figures mark the location of variance peaks, where the wavenumber width defines their half-power bandwidth. Shading indicates log variance density within the half-power bandwidth. The solid lines are the theoretical plane beach dispersion curves for the edge wave modes (0, 1, 2, . . . 10). The solid line in the vertical panel on the right is the frequency spectrum. The dashed line indicates the percent of total power in each frequency bin that is shown in the k-f spectrum.

Data matrices were generated from k-f spectra simulating beach slopes of 0.02, 0.04, 0.06, 0.08, and 0.10 and observation depths of 2, 5, and 8m. Figures 1.1.3-8 and -9 summarize the results from the matching of these matrices against the library of test templates. The estimation of the beach slope is not bad, but is also not perfect (Figure 1.1.3-8). Interestingly, the estimation of observation depth is worse (Figure 1.1.3-9). This may be in part a result of our less than accurate mimicking of the mode jump locations in the test templates (section 1.1.3.1), which are a function of the observation depth. A better tuning may improve these observation depth estimations and possibly also the beach slopes estimates. However, as demonstrated below, improvement in the beach slope estimate is also expected if we apply a priori information about the observation depth.

We explore the latter point with Figure 1.1.3-1-10. The highest score in Figure 1.1.3-10 is 61. This is also the score of the correct match (slope = 0.02, depth = 2m). The next highest score is 52 (from a template with a different beach slope, 0.025, and observation depth, 3m). The difference in the scores is +9. However, if we knew the observation depth a priori (which we would), then the next highest score would be 45 (from a template with a beach slope of 0.025 but the same observation depth). The difference between this score and the true score is +16; we have effectively reduced the noise floor by only matching to test templates with the same observation depth.

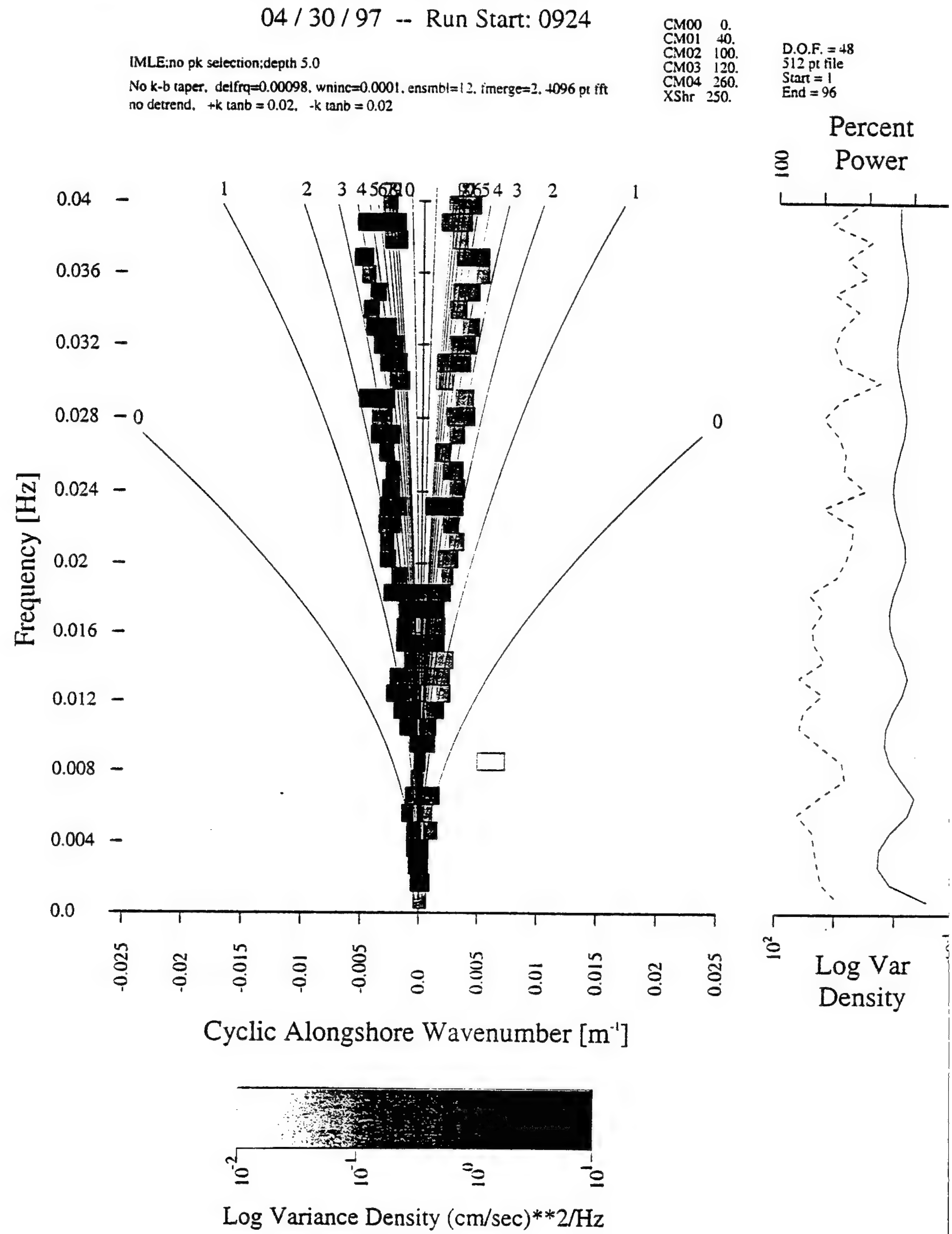


Figure 1.1.3-5. Simulated k-f spectrum for a beach of slope 0.02 and observation depth of 5m.

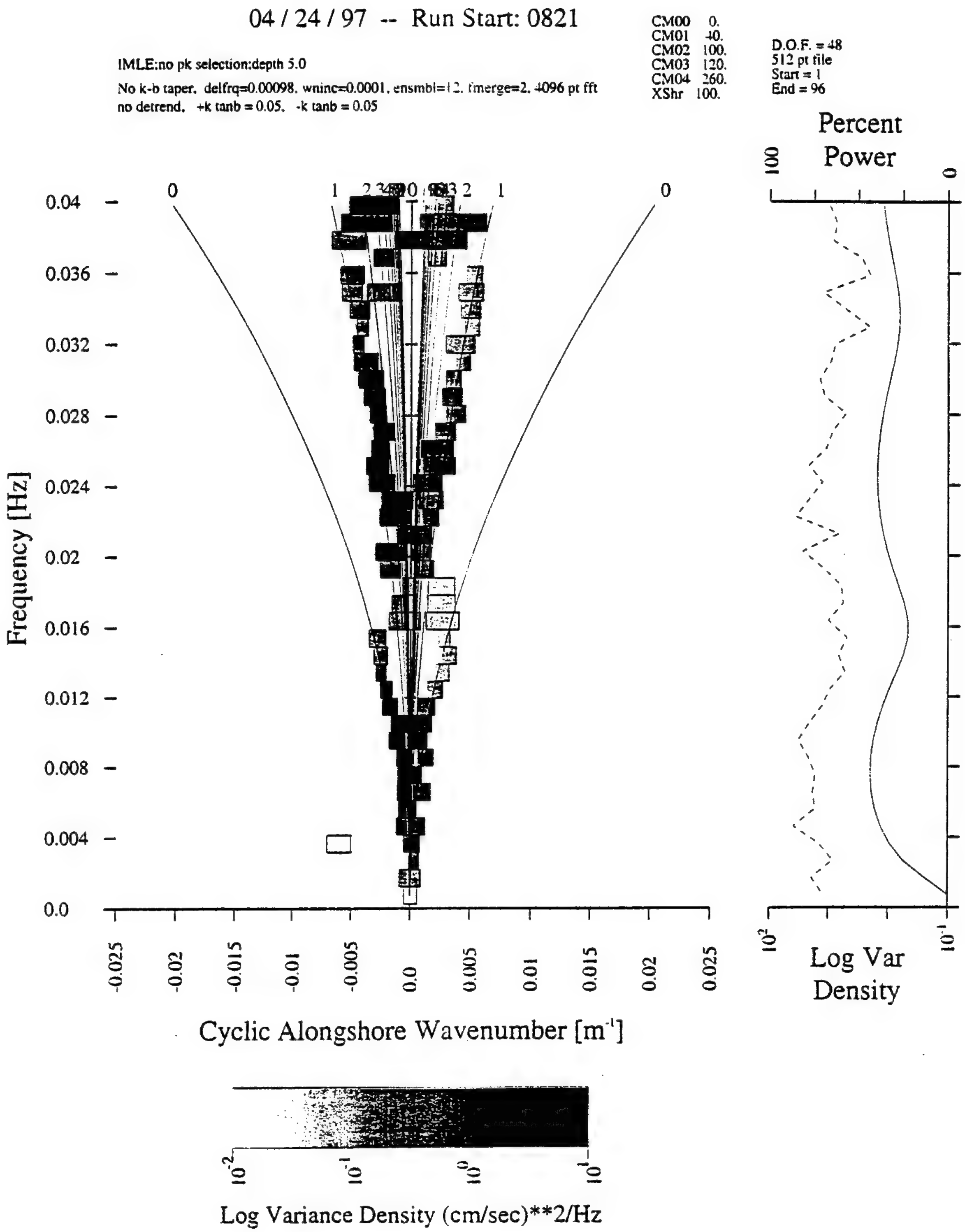


Figure 1.1.3-6. Simulated k-f spectrum for a beach of slope 0.05 and observation depth of 5m.

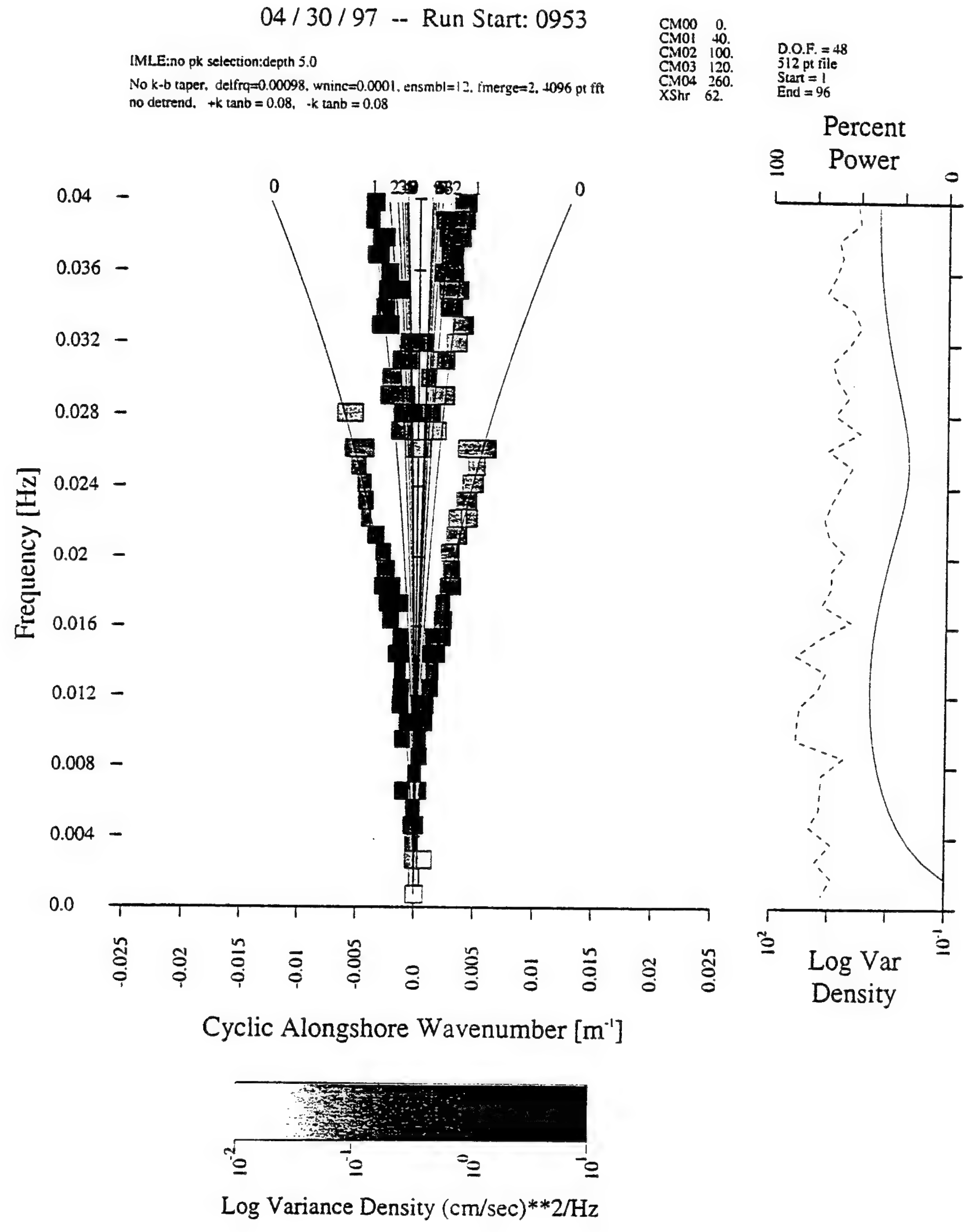


Figure 1.1.3-7. Simulated k-f spectrum for a beach of slope 0.08 and observation depth of 5m.

The estimated beach slope [resulting from matching each simulated (noisy) data matrix against the library of test templates] plotted against the true beach slope.

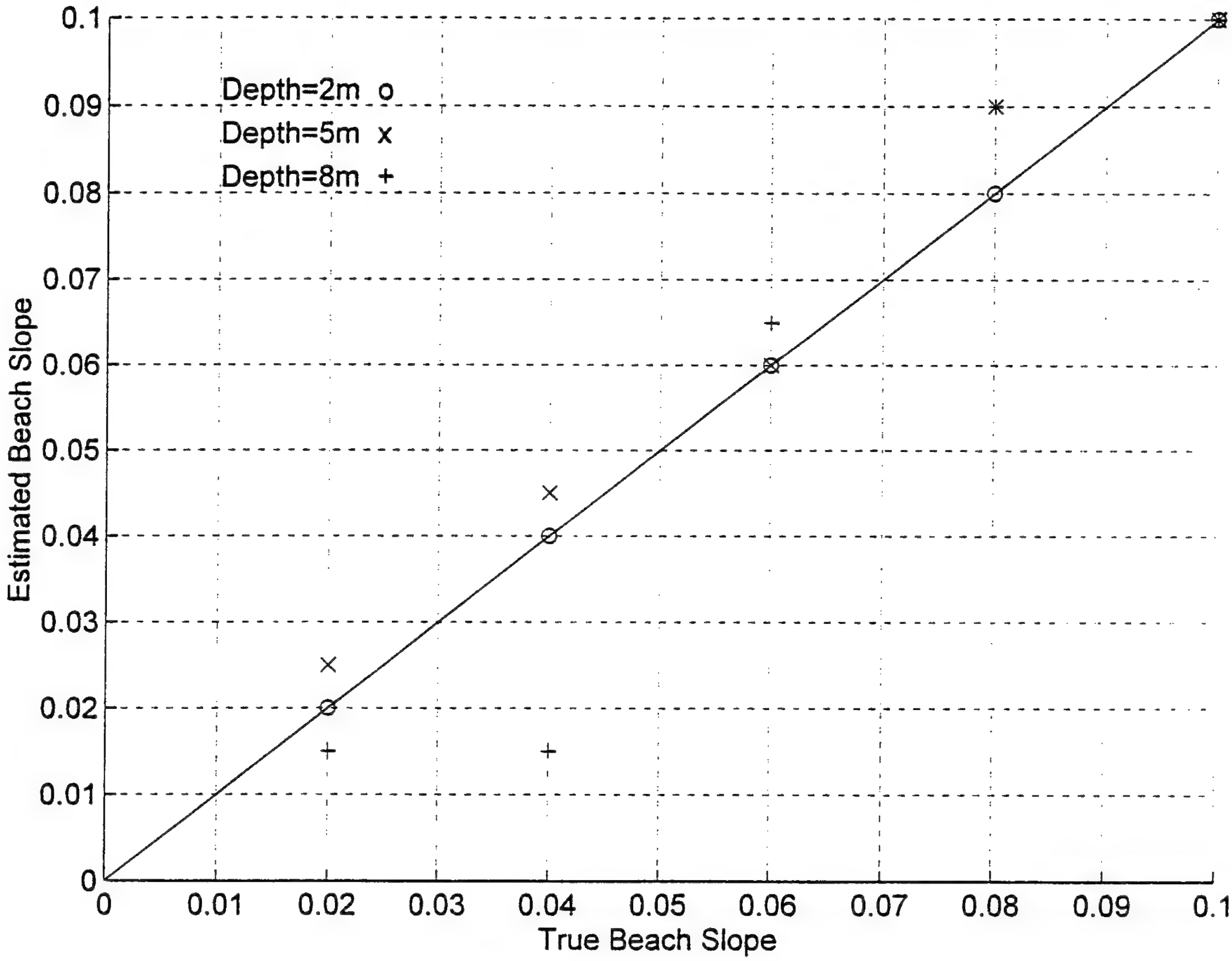


Figure 1.1.3-8. Plot of estimated versus true *beach slope* for a range of slopes and observation depths.

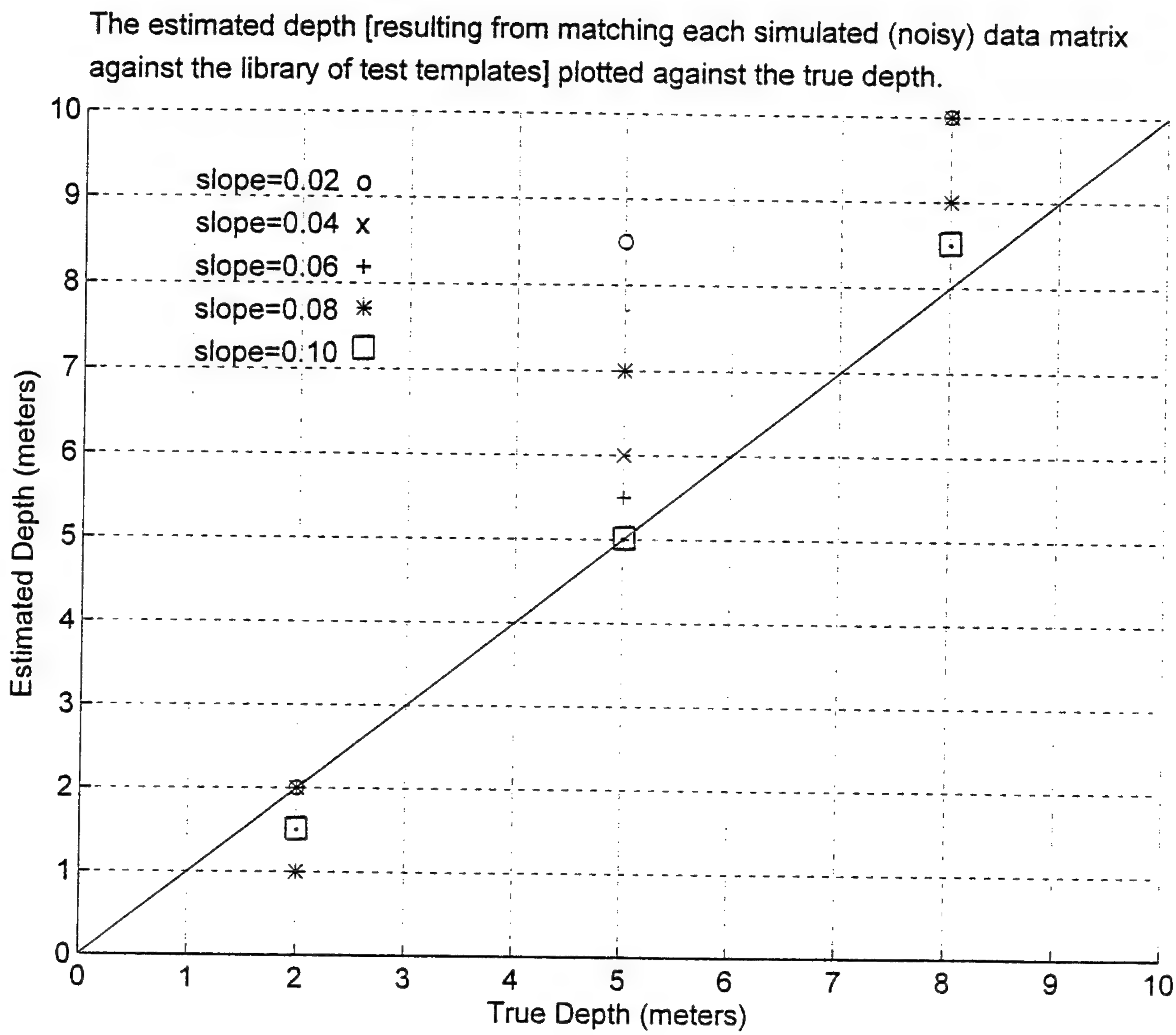
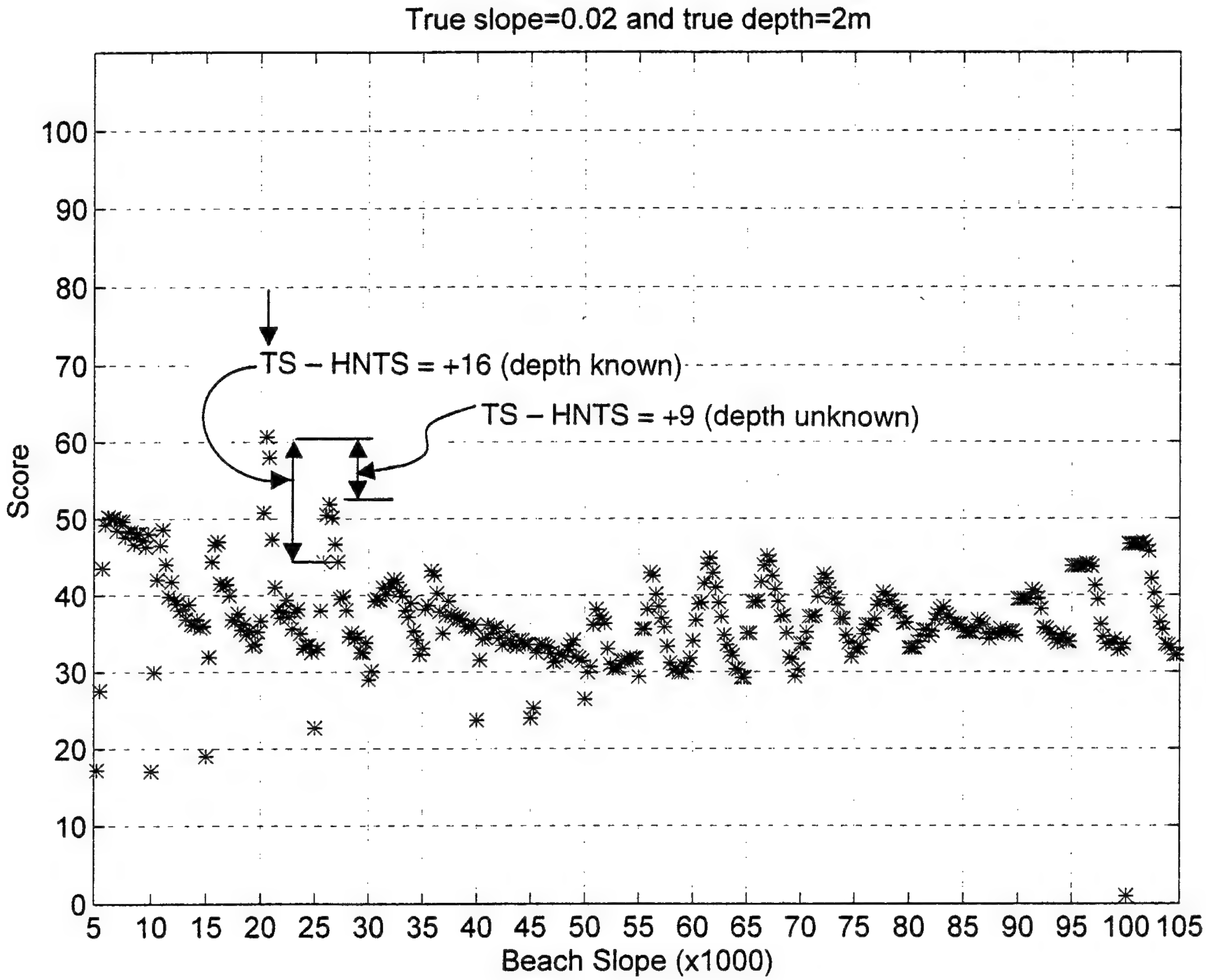


Figure 1.1.3-9. Plot of estimated versus true observation *depth* for a range of slopes and observation depths.

Scores resulting from matching a single simulated data matrix against the library of test templates.



Each tick marks the start of a new slope in the library of test templates. The stars within each tick identify scores for each depth from 1 to 10m in steps of 0.5m.

Figure 1.1.3-10. Template matching scores for a simulated data matrix (0.02 slope and 2m observation depth) against the library of templates. The down arrow identifies the correct match and, encouragingly, also the highest score. A comparison between the True Score (TS) and the Highest NonTrue Score (HNTS) is shown for the case in which 1) depth of observation is not assumed known and 2) depth of observation is assumed known.

The benefit of a priori knowledge of the depth of observation can be demonstrated in Figures 1.1.3-11 and -12. The difference between the True Score and the Highest NonTrue Score is plotted for a single stochastic realization of data matrices representing a sample range of slopes and depths. Figure 1.1.3-11 plots the score difference when the observation depth is not assumed to be known. A positive difference indicates that a correct match (a correct beach slope estimate) will be made; a negative difference indicates an incorrect match will be made. In Figure 1.1.3-11, there are five correct matches, three ties between a correct match and an incorrect match, and six incorrect matches. Expectedly, there are more correct matches for a 2m observation depth than for a 5 or 8m observation depth for this set of stochastic realizations. However, before trying to read anymore into this plot, we turn to Figure 1.1.3-12 which shows the difference scores with the assumption that the observation depth is known.

Shown in Figure 1.1.3-12 are ten correct matches and only three incorrect matches. Comparing Figure 1.1.3-11 with -12 shows that Figure 1.1.3-12 has larger positive scores and smaller negative scores. The mismatch indicated for a 0.02 slope observed at 5 and 8m depth is in part a problem with resolution of the k-f spectra for those larger offshore observation distances (250m and 400m) and concomitant low-slope depth profiles (compare Figure 1.1.3-13 with 1.1.3-1 and -3). However, further examination of the matching results discussed below will show that these mismatches nonetheless approximate the correct match.

Thus far we have only looked at one simulated stochastic realization of each data matrix. We now examine the stability of the matching by running 50 stochastic realizations of each of the beach slopes 0.02, 0.05, and 0.08 and with one observation depth (5m). Histograms of the matched beach slopes and matched observations depths are shown in Figures 1.1.3-14a,b through -16a,b. Note that we have not used the a priori knowledge of the observation depth with these matches, hence the histograms of matched depths.

Two clear patterns emerge. One, the matched beach slopes and depths are clustered around the true beach slope and depths. This is good; there may not be 100% repeatability, but there is stability. Two, the matching of depths is much worse than the matching of beach slopes. The latter point suggests that we should attempt to improve our matching of depths before using the a priori knowledge of observation depth in the beach slope matching. This implies a need to further tweak our library of test templates. Nonetheless, from the discussion above (Figures 1.1.3-11 and -12), we know that a priori knowledge of the observation depth will significantly improve the results shown in Figures 1.1.3-14a, -15a, and 16a.

Difference between the True Score (score from matching a single simulated data matrix against the true template for that slope and depth) and the Highest Nontrue Score (highest score from matching the single simulated data matrix against the library containing all of the test templates except the true one). Assumes depth is unknown.
A positive difference means that the true score was higher, so the true slope and depth was selected. A negative difference means that the highest nontrue score was the optimal score for that match, so the incorrect slope and/or depth was selected (however, the slope selected was within 0.01 of the true slope).

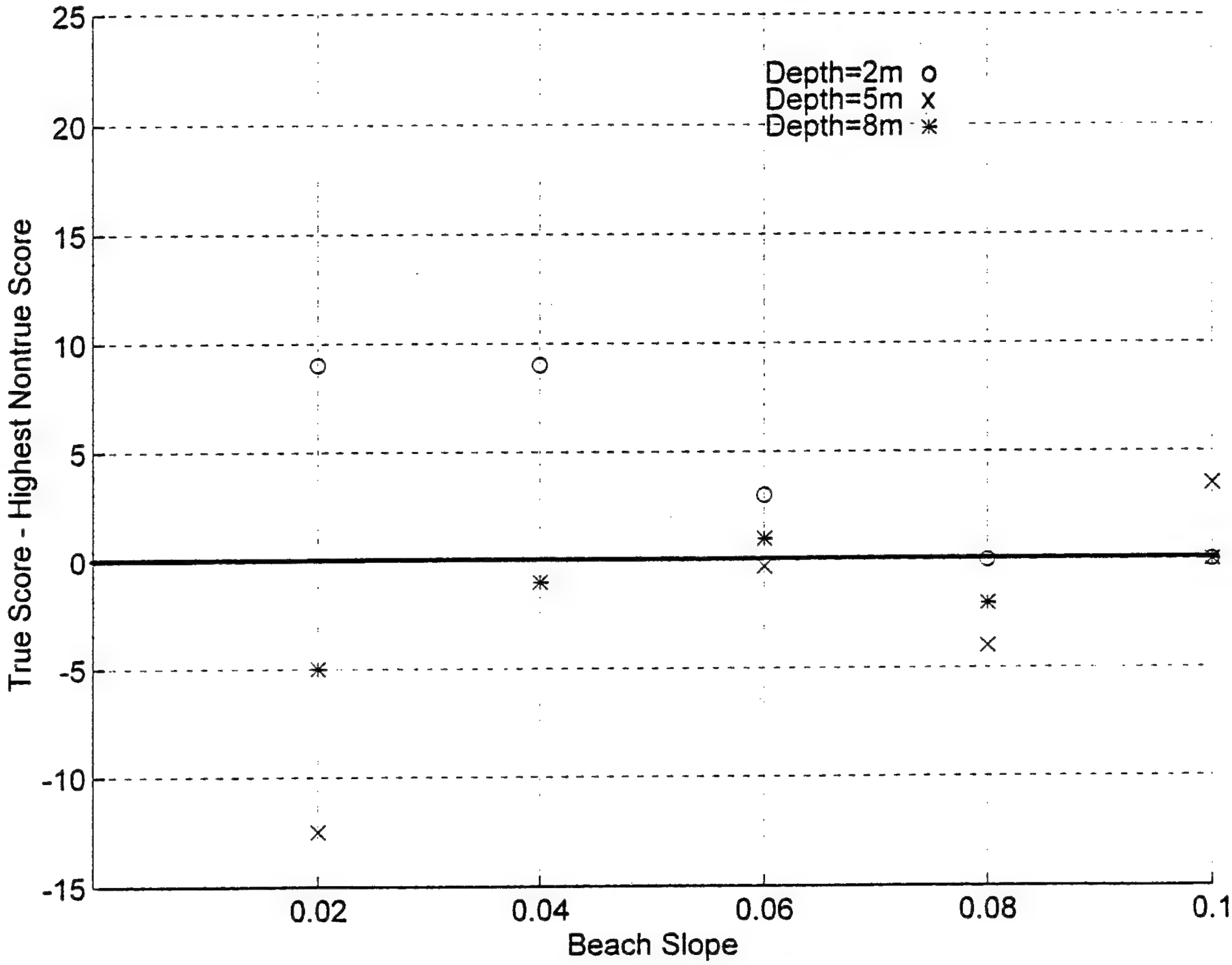


Figure 1.1.3-11. Difference between the True Score (score from matching a single simulated data matrix against the true template for that slope and depth) and the Highest NonTrue Score (highest score from matching the single simulated data matrix against the library containing all of the test templates except the true one). Assumes depth is *unknown*.
A positive difference means that the true score was higher, so the true slope and depth was selected. A negative difference means that the highest NonTrue score was the optimal score for that match, so the incorrect slope and/or depth were selected (however, the slope selected was within 0.01 of the true slope).

Difference between the True Score (score from matching a single simulated data matrix against the true template for that slope) and the Highest Nontrue Score (highest score from matching the single simulated data matrix against the library containing all of the test templates except the true one). Assumes depth is known.
A positive difference means that the true score was higher, so the true slope was selecte
A negative difference means that the highest nontrue score was the optimal score for tha
match, so the incorrect slope was selected (however, it was within 0.005 of the true slope

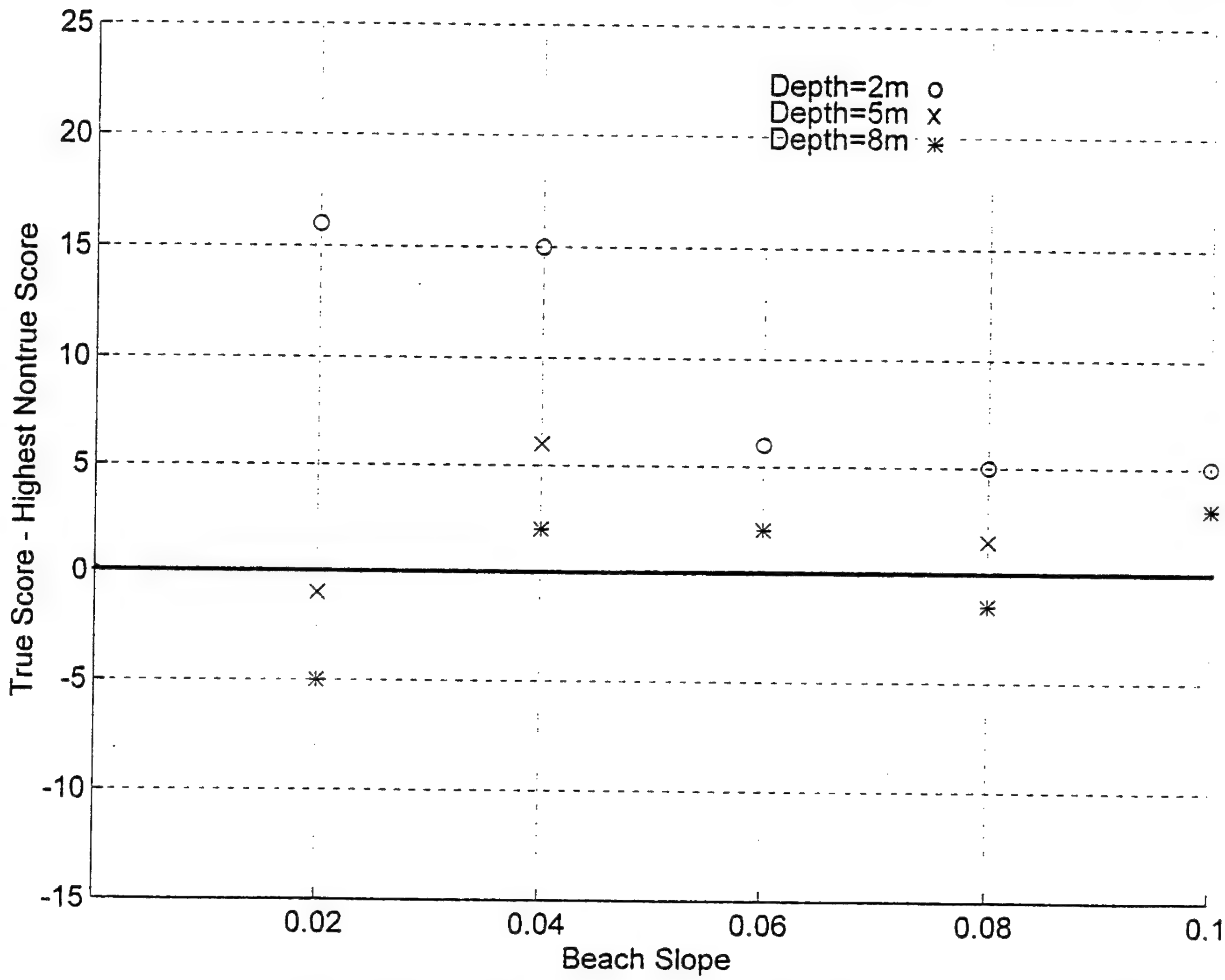


Figure 1.1.3-12. Difference between the True Score (score from matching a single simulated data matrix against the true template for that slope) and the Highest NonTrue score (highest score from matching the single simulated data matrix against the library containing all of the test templates except the true one). Assumes depth is *known*. A positive difference means that the true score was higher, so the true slope was selected. A negative difference means that the highest NonTrue score was the optimal score for that match, so the incorrect slope was selected (however, it was within 0.005 of the true slope).

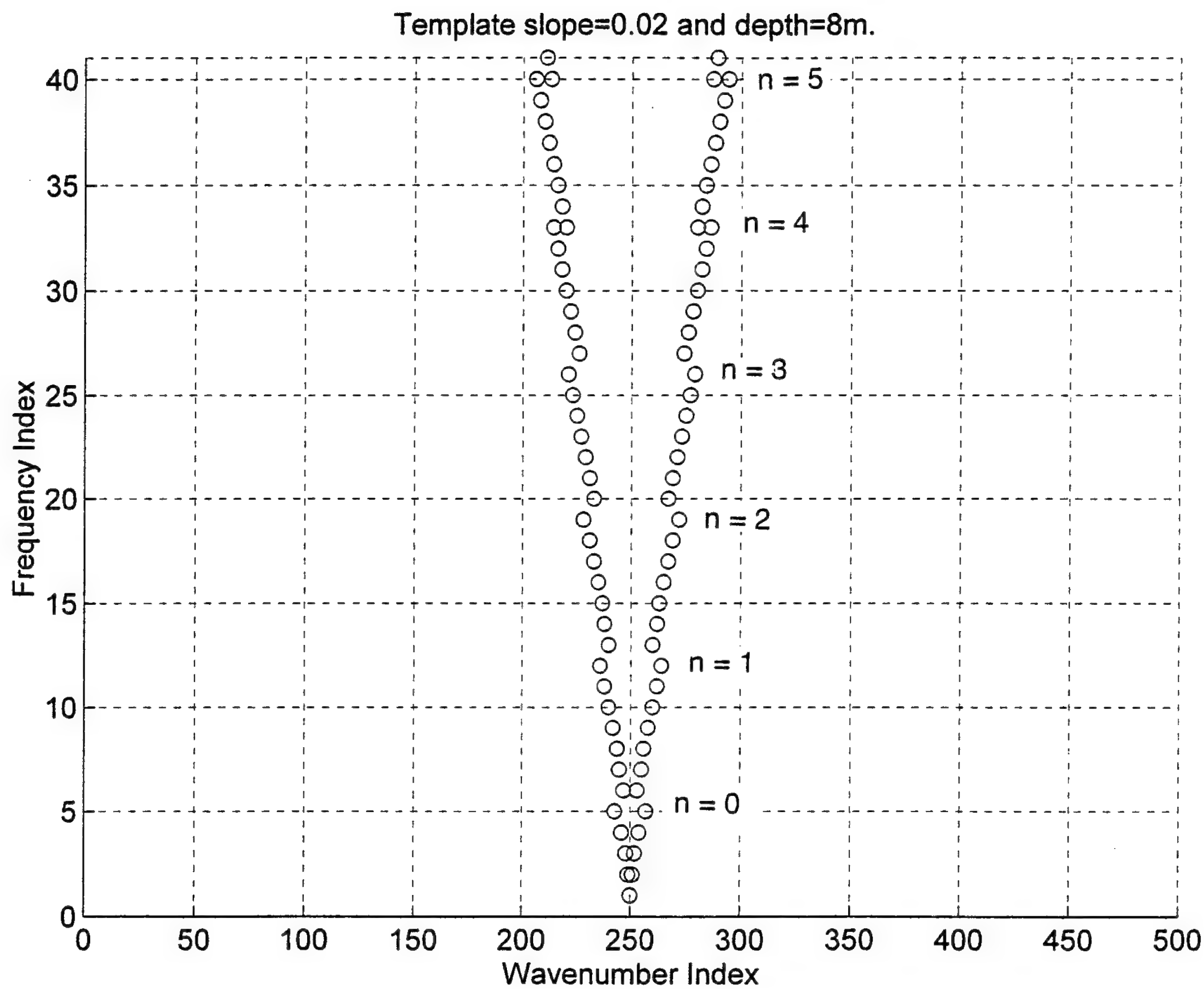


Figure 1.1.3-13. Example test template (beach slope = 0.02, observation depth = 8m).

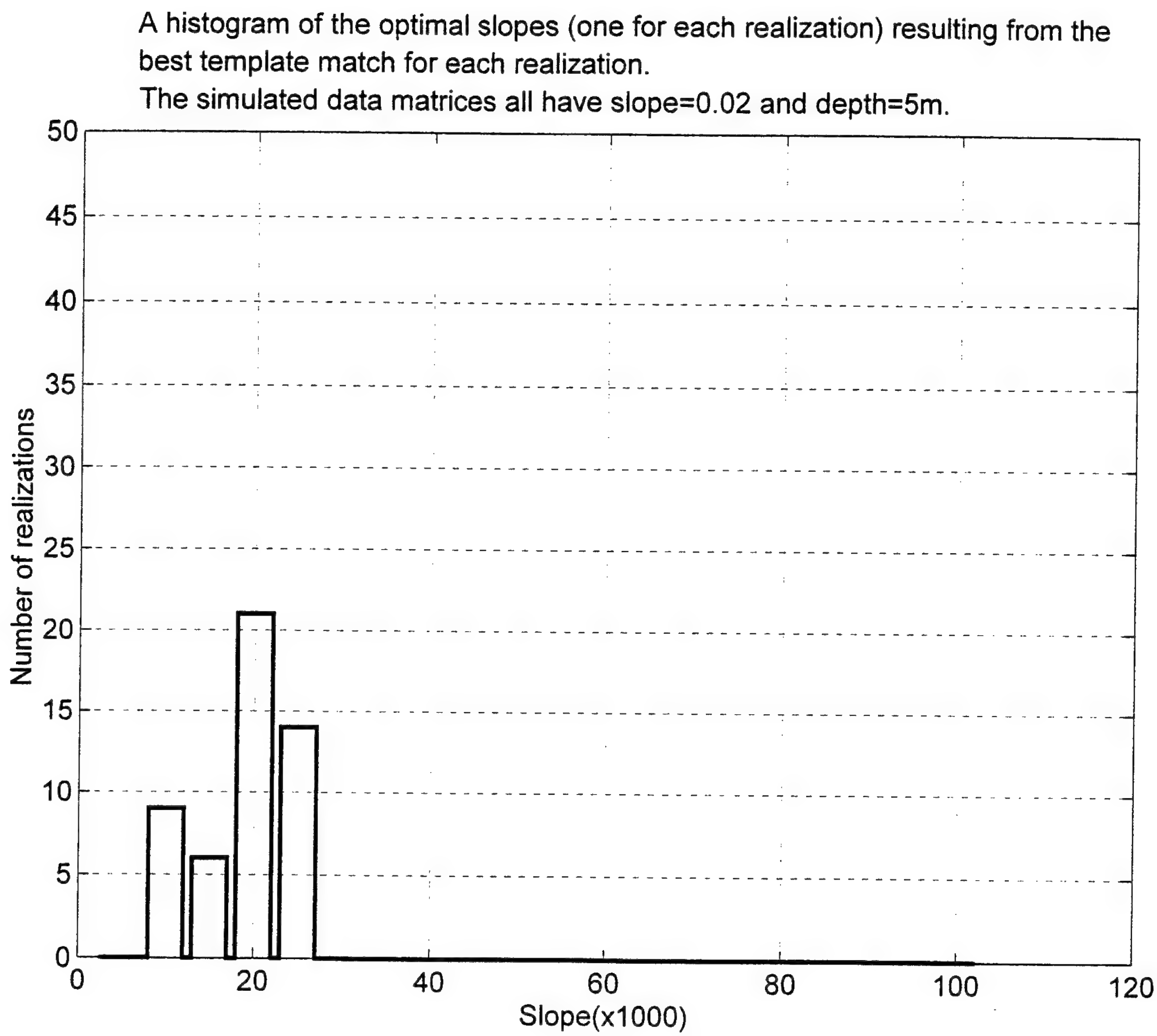


Figure 1.1.3-14a. Histogram of estimated beach slopes for 50 stochastic realizations (beach slope = 0.02, observation depth = 5m).

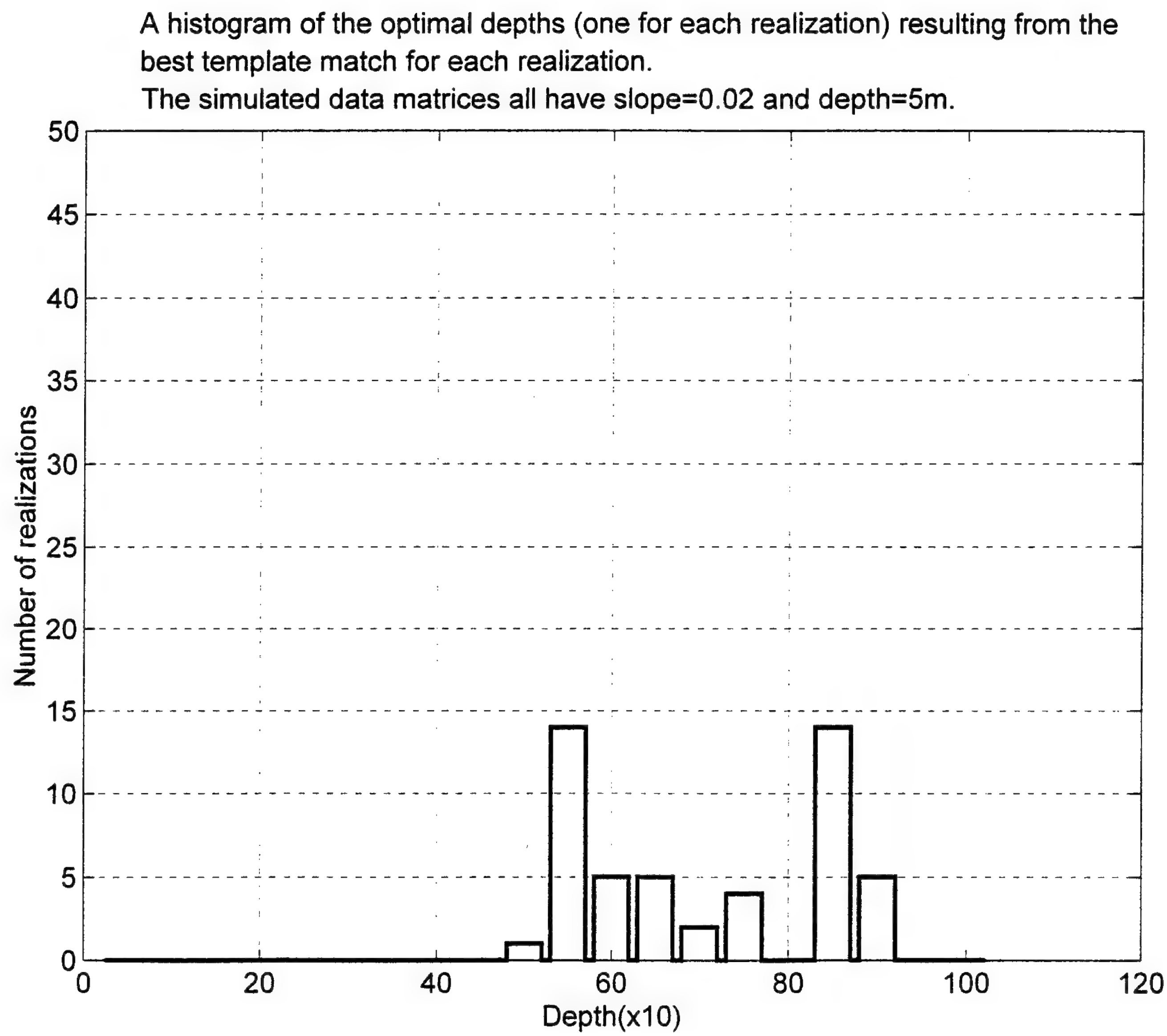


Figure 1.1.3-14b. Histogram of estimated observation depths for 50 stochastic realizations (beach slope = 0.02, observation depth = 5m).

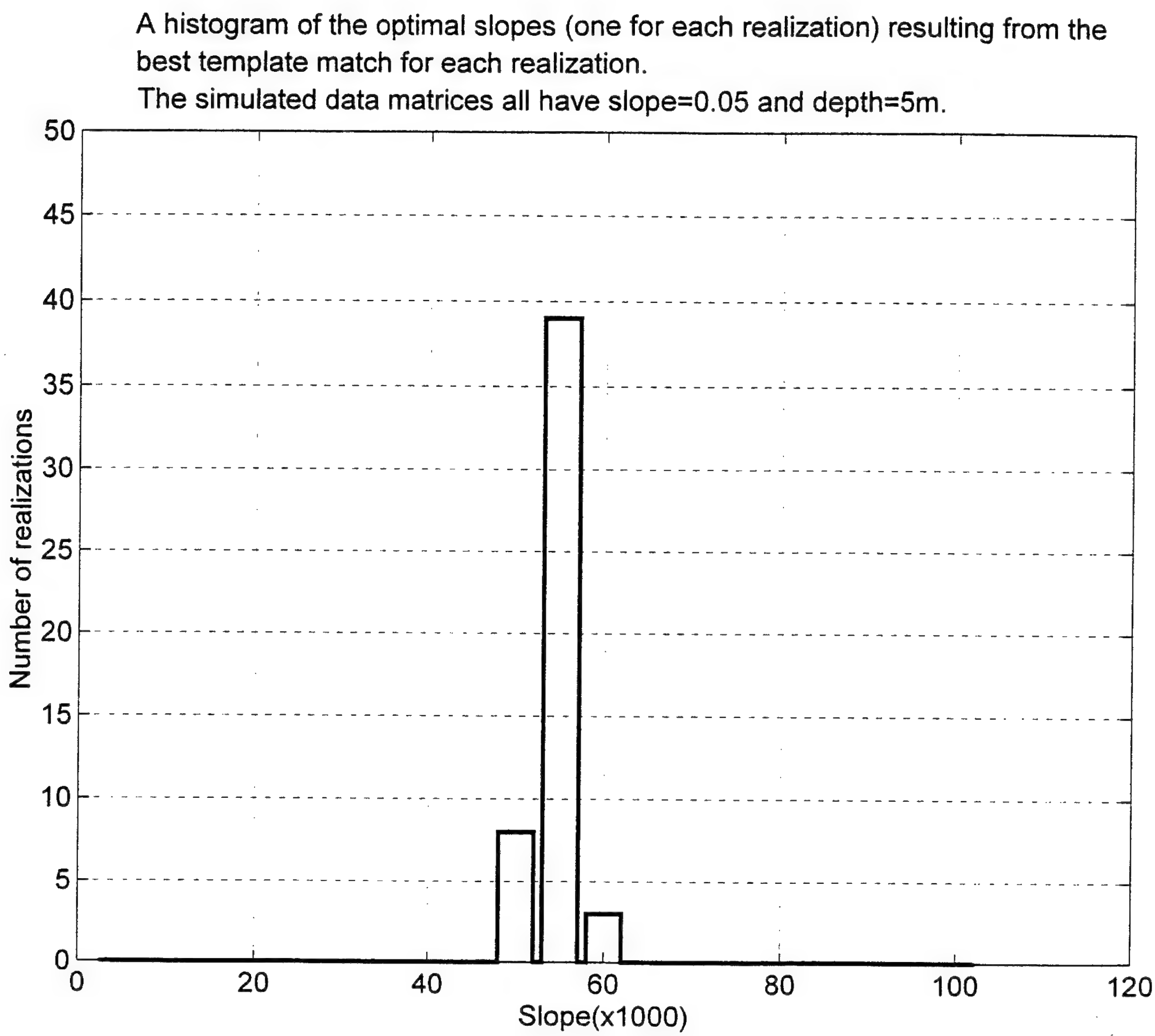


Figure 1.1.3-15a. Histogram of estimated beach slopes for 50 stochastic realizations (beach slope = 0.05, observation depth = 5m).

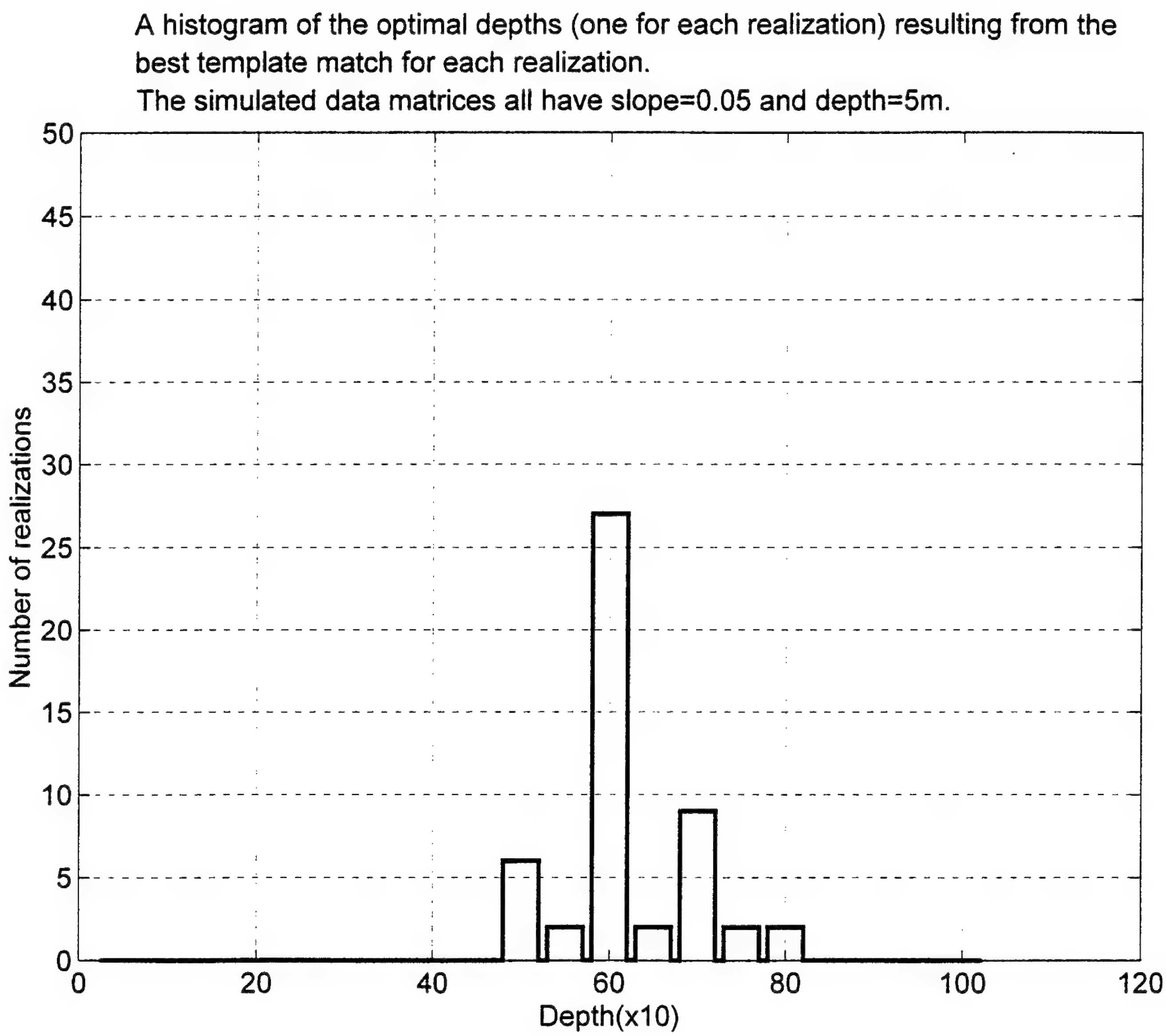


Figure 1.1.3-15b. Histogram of estimated observation depths for 50 stochastic realizations (beach slope = 0.05, observation depth = 5m).

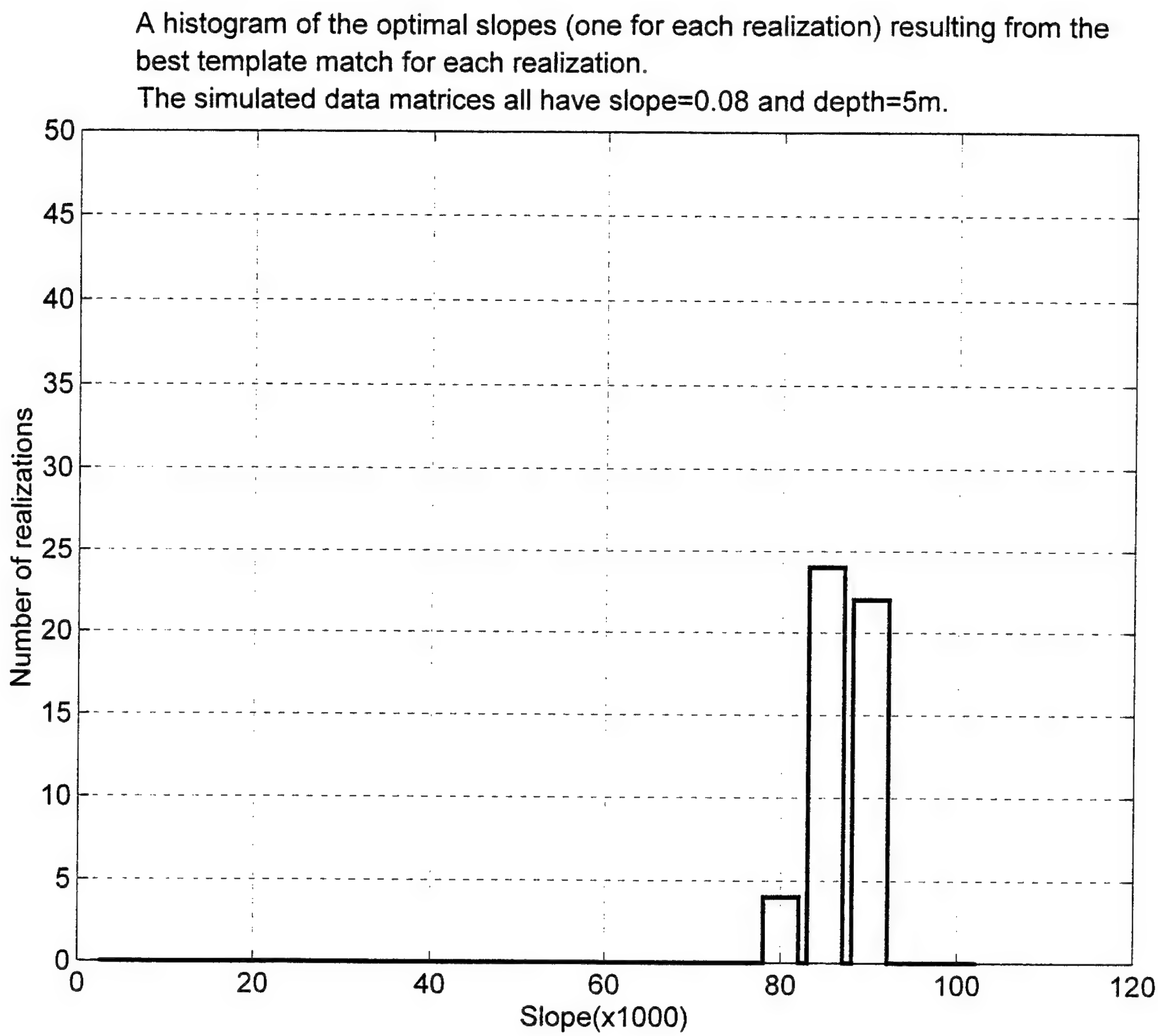


Figure 1.1.3-16a. Histogram of estimated beach slopes for 50 stochastic realizations (beach slope = 0.08, observation depth = 5m).

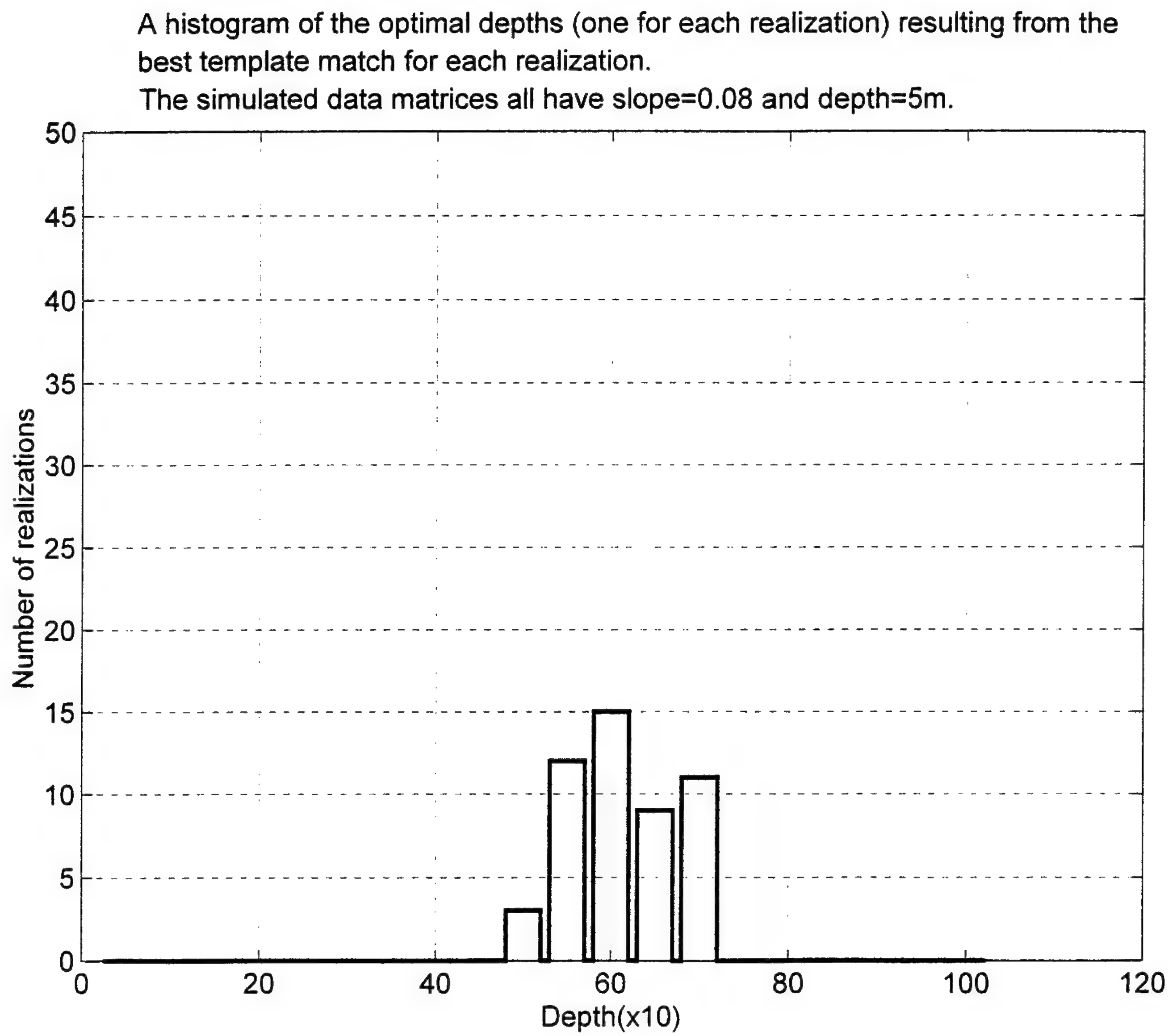


Figure 1.1.3-16b. Histogram of estimated observation depths for 50 stochastic realizations (beach slope = 0.08, observation depth = 5m).

1.1.3.2.3 Summary and Conclusions

The lessons learned from our study of the Template-Matching Technique (TMT) serve well to direct our work over the next six months. Thus far we have restricted our study to plane-slope beaches. Clearly, we will soon need to study the behavior of the TMT for data matrices from nonplanar depth profiles matched against a library of templates for planar depth profiles. However, there remain a few more plane beach issues to resolve.

It was shown in Figures 1.1.3-14 through -16 that the estimation of observation depth is poor in comparison to the estimation of beach slope. The poor matching may be improved by using a higher depth resolution of templates in the library (e.g., increments in depth of 0.2m instead of 0.5m) and/or a finer tuning of the mimicking of the mode jump locations. The latter point will require a more complete analysis of the simulated behavior of the array geometry in tandem with the Iterative Maximum Likelihood (IML) wavenumber estimator. We are hopeful that a benefit of the improvement in the estimation of the observation depth might also yield an improvement in the beach slope estimation, with and without a priori knowledge of the observation depth. After a tuning of the TMT, we can then do a thorough study of the stability of the estimation to address questions such as how often will we get incorrect answers and how incorrect will they be. This will have an impact on the second step in the inverse problem, the inversion of the first-order perturbation expansion. The study of the influence functions suggest that the choice of the plane-beach slope (zeroth order) approximation might affect the resolution of the first-order correction (Appendix A). How the zeroth-order depth profile affects the first-order edge wave solutions will be studied over the next six months.

We are also planning to begin the study of nonplanar depth profiles applied to the TMT. We will begin the study by using an analytic, exponential depth profile (foreshore steepening). However, we will quickly move to representative summer and winter depth profiles of Duck, NC, in preparation for the Fall 1998 experiment.

1.1.4 Defining BPS Criteria of Success

At the 14 Nov 96 Advisory Panel meeting, the need to define criteria with which to assess the success of BPS was discussed. This section addresses that issue. Below, we discuss measures of success that may apply to the BPS project and begin to build a framework from which we can define these criteria.

Several terms are commonly used in the Navy to define success of a technology:

- Measure of Performance (MOP) – used to define the performance of a piece of hardware for a given operational setting.
- Measure of Exit (MOE) – used in the 6.3/6.4 community to define the criteria to be met if a technology is to be transitioned to operational Navy. This is different from a MOP in that it considers the value of a technology for Naval operations.
- Measure of Effectiveness – commonly used to define the success of a suite of complimenting instruments in an operational setting (e.g., METOC success in applying a suite of instruments to define a coastal environmental condition).

- Measure of Success (MOS) – typically used to define the success of an operational objective (e.g., landing safely on a beach).

Again, the above terminology is applied only to technology. Measures that are appropriate for the BPS technology are **Measure of Performance** and **Measure of Exit.** However, from a programmatic point of view, the BPS project must also set criteria by which to judge the success of the project. We refer to this a **Measure of Project Success (MOPS).**

Both the Measure of Project Success and the Measure of Exit can and should be defined early in the BPS project. We have begun this process in the following sections. The Measure of Performance is one of the objectives of the BPS project. The MOPS will be completed by the end of this project.

The following is intended to be used as framework from which to begin a dialogue with the Advisory Panel on the definitions of the MOPS and MOE. The definitions presented below are expected to evolve through discussions with the panel and the program manager, Dr. Tom Kinder.

1.1.4.1 Measure of Project Success (MOPS)

The BPS project was designed to

1. Develop a technology to extract surf zone environment information (i.e., 1-D depth profile, alongshore current magnitude and direction, breaker height, location, and surf zone width) from measurements of the wind and infragravity wave fields acquired outside of the surf zone; and
2. Define the performance of such a technology in relevant operational scenarios.

Therefore, the BPS project will have been a success if, at the end of the term, it extracts surf zone environmental information from measurement of wind and infragravity waves and quantifies the resolution and confidence of that information for relevant Naval operation scenarios. If and how this translates to a MOPS for the BPS project is open for discussion.

Intermediate Measure of Project Success

In addition to an overall MOPS, the BPS project needs intermediate check points, or intermediate MOPS, to help assess the project's progress and potential overall success. In evaluating the program, questions could be framed about a set of intermediate MOPS. For instance:

1. Have the intermediate criteria successfully been met?
2. If not met, how can the model and/or equipment, etc., be changed to make it successful.

An example of an intermediate criterion is one we have set internally for our Spring 1997 study of the potential feasibility of an inverse technique, the Template Matching method.

- The inverse method must show promise for achieving a stable, converging beach slope estimation over a range of measurement depths greater than 2m and for a broad range of natural planar beach slopes.

1.1.4.2 Measure of Exit (MOE)

(Contributing Author: Stu Knoke)

It is useful in the early stages of the BPS project to identify capabilities that the BPS technology must meet to be of value to the operational Navy. This not only lends itself to a potentially more rapid transition to operation because clearly defined measures of exit have been made a priori, but also helps to ensure that the BPS technology, with this awareness and perspective, develops along a path with highest probability of transition.

To begin defining a MOE for the BPS technology, we start by gathering information about other surveillance technologies that are available or are in transition to the operational Navy. It is our objective to construct a MOE for the BPS technology within the framework of this information. Tables 1.1.4-1 and 1.1.4-2 provide organization to the information we are presently acquiring about surf zone environmental surveillance systems. In section 1.1.4.2.1, we explore in detail the hydrographic surveying technique of the SEAL teams and begin a study of the expected error in beach slope estimates from their approach.

1.1.4.2.1 SEAL Team Hydrographic Reconnaissance Analysis

SEAL (Sea, Air, and Land) combat teams are used for reconnaissance of beaches for amphibious landing practice, landing troops on relatively safe beaches, and landing troops on unsafe beaches. Three basic hydrographic reconnaissance methods are employed by the SEAL teams:

1. Perpendicular Reconnaissance (administrative reconnaissance for amphibious landing practice)
2. Parallel Reconnaissance (combat reconnaissance of a relatively safe beach)
3. Underwater Reconnaissance (clandestine reconnaissance of an unsafe beach)

The SEAL teams are responsible for reconnaissance of a beach from the 21-foot depth contour to shore. All methods map the hydrography (i.e., bathymetry) on a 25x25-yard grid. The survey width of a beach varies from 200m to a few kilometers.

Described below is the general methodology of each type of reconnaissance. In addition, the latter two combat reconnaissance methods are analyzed for their inherent hydrographic resolution and accuracy.

1.1.4.2.1.1 Perpendicular Reconnaissance

Perpendicular reconnaissance is an overt, daytime beach reconnaissance used primarily for amphibious landing practices. As illustrated in Figure 1.1.4-1(a), a platoon or more (16 to 24) of surface swimmers line up perpendicular to shore. The team member farthest offshore holds position above the 21-foot depth contour while the rest of the platoon swims inshore pulling a line (rope) marked at 25-yard intervals. They align themselves perpendicular to the beach using a pair of markers on the beach. After the team members measure the water depth with a line and lead weight, search the area for debris, and log each depth, they move alongshore 25 yards, aligning themselves with another pair of markers on the beach. We will not address this method further since it is not used in a combat setting.

Table 1.1.4-1. Review of Surf Zone Reconnaissance Methods – A. Advantages and Limitations

Tool	Operational Advantages	Operational Limitations
SEAL Team	•Direct visual observations and interpretation •Clandestine	•High risk to personnel •Provides only spot checks in space and time •Requires post processing for hydrography hours to days •Conditions must be within swimmer operations critical thresholds: Currents < 1kt, Surf (any type) < 5 ft, Swimmer invisible in 10 ft water under ambient or luminescent lighting, Offshore height (of combined seas) < 3 ft.
UUV	•Mobile underwater observations •Clandestine	•Requires a host ship offshore •Provides only spot checks in space and time •Data recovery delay of several hours to days •Conditions must be within operational critical thresholds: TBD
BPS	•Continuous unattended measurements from offshore, underwater location •Clandestine	•Requires accurate placement by UUV or divers using GPS •Requires telemetry, UUV link, or com line for data •Long time in place increases detection potential
Hydrophones and Seismo meters	•Continuous unattended measurements from offshore, underwater location •Clandestine	•Requires accurate placement by UUV or divers using GPS •Requires telemetry, UUV link, or com line for data •Longtime in place increases detection potential

Table 1.1.4-1(cont.). Review of Surf Zone Reconnaissance Methods – A. Advantages and Limitations

Tool	Operational Advantages	Operational Limitations
LIDAR	•Remote, above water on piloted platform •Broad spatial coverage •Direct measurement	•Requires moderately clear water (therefore cannot measure in surf zone unless low waves) •Requires airborne platform (vulnerable to AAW) •Intermittent temporal coverage
Video	•Remote, above water on piloted platform •Broad spatial coverage	•Data only in surf zone •No data in fog or in calm seas •Requires airborne platform to provide video of fixed location for several minutes •Intermittent temporal coverage •No data during high wind/wave conditions (confused seas)
SAR	•Remote, above water on piloted platform or satellite •Broad spatial coverage •Satellite SAR -- Immediate data source, covering whole planet every few days	•Unproven for application in surf zone •Airborne SAR -- Requires platform •Intermittent temporal coverage •No data during high wind/wave conditions (confused seas)

Table 1.1.4-2. Review of Surf Zone Reconnaissance Methods – B. Information Provided and Approach

Tool	Information Provided	Data Collection Approach	Resolution and Confidence
SEAL Team	•Presence and location of sand bars, debris, obstacles, mines, and defenses •Hydrography and trafficability •Qualitative estimates of: Wave incident angles to the beach Breaker heights and types (spilling, plunging, and collapsing) Current (longshore and under tow) Ocean bottom material (fine sand, cobble)	•Divers provide direct point measurements using depth gauges, GPS, and kick counts (for relative distance) (NOTE: The CLAM technology will be considered later.)	•Coverage time = several hours? •Resolution of beach slope = 10% on plane parallel beaches •Resolution of breaker heights = +/-30cm •Resolution of currents = 20% •Resolution of trafficability = qualitative go/no go Repeatability (i.e., confidence)?
UUV	•Hydrography •Currents •Location of bars and debris •Breaker height •Location •Wave heights and direction	•Instruments and video camera on UUV provide direct point measurements	•Coverage time? •Resolution of beach slope, breaker heights, and currents? •Repeatability (i.e., confidence)?
BPS	•Alongshore averaged (~100m) estimates of nearshore beach slope including surf zone and shore line features (e.g., steep foreshore, tidal terraces) •Wave heights and direction •Breaker height and location, and probable breaker type (i.e., spilling, plunging, and collapsing) •Surf zone width •Longshore current direction and magnitude	•Spatial array of 5-7 sensor packages placed on bottom outside the surf zone to directly measure the local surface-gravity wave (i.e., sea, swell, and infragravity) directional spectra •Indirect estimates (using inverse techniques) of depth profiles, longshore currents, etc.	•Plane beach slope approximation TBD Summer 1997 (refined Winter 1998/99) •Nearshore features (e.g., steep foreshore) TBD Winter 1998/99 •Longshore current TBD Winter 1998/99 •Sea and swell wave spectra TBD Winter 1998/99 •Breaker location, surf zone width TBD Fall 1999

Table 1.1.4-2 (cont.). Review of Surf Zone Reconnaissance Methods – B. Information Provided and Approach

Tool	Information Provided	Data Collection Approach	Resolution and Confidence
Hydrophones and Seismometers	•Ocean bottom material (fine sand, cobble, hardrock sublayer) •Presence and location of surf zone •Local wave amplitude and direction •Breaker height and type	•Spatial array of acoustic or seismic sensors directly measures the overlying wave field •Indirect estimates of the bottom material, presence of surf zone, breaker height and type, etc.	•Wave directional spectra? •Ocean bottom material? •Location of surf zone? •Breaker height and type?
LIDAR	•2-D topographic map of nearshore from 1m to 40m depth, depending on water clarity •Location of debris and obstacles larger than 2-m cube	•Laser light detection and ranging to measure water depth and beach topography	•± 15cm vertical and 3m horizontal resolution from helicopter •30 m horizontal resolution for high-flying aircraft with current hardware
Video	•2-D map of sand bars and large •Surf zone depth profile and width •Breaker location and type •Longshore currents in surf zone	•Video acquired from above water for 5-10 min; interpret images to locate breaking waves, and measure bore speed	•Pixel size = cm? •Image size = ? Resolution of: •current vector = ? •sand bar location = ?
SAR	•2-D map of surface currents and water depth	•Synthetic aperture radar images of capillary waves, or surface currents •Indirect estimates of water depths from either wave refraction patterns or interferometric analysis of wave propagation speed	•Pixel size? •Image size? Resolution of: •current vector? •bathymetry?

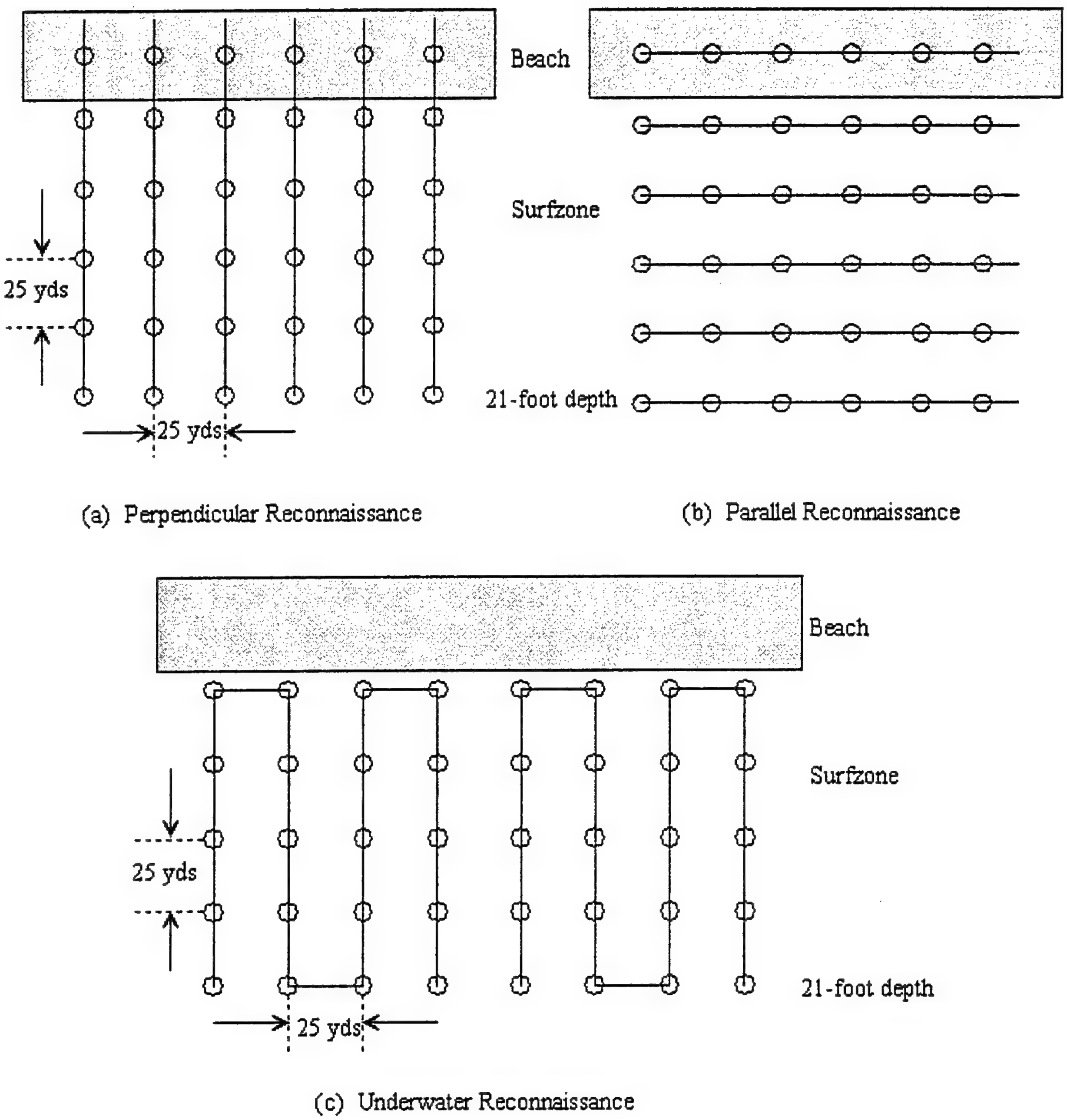


Figure 1.1.4-1. Basic beach hydrography methods used by SEAL teams. Circles denote the depth measurement location while lines show either the alignment of the SEAL team for a synchronous depth sampling (a, b) or the survey pattern of a swimmer (c).

1.1.4.2.1.2 Parallel Reconnaissance

Parallel reconnaissance is used in a combat situation on a relatively safe beach. A platoon swims on the surface to the 21-foot depth contour and lines up parallel to that contour or to the beach, spaced at roughly 25 yards [Figure 1.1.4-1(b)]. After the depth measurement, the platoon logs the depth, searches the area for debris, and advances 25 yards towards the beach. When they have repositioned themselves, they make another depth measurement. This process is repeated until they are all near or onshore.

At present, it is not clear to us which of the following procedures are used by the SEAL teams for parallel reconnaissance:

Case 1. Each swimmer starts at roughly the 21-foot depth contour. A tag line is used to keep the swimmers aligned and spaced exactly 25 yards apart for all measurements. The team members on opposite ends of the line hold it taut, which aids in their maintaining alignment.

Case 2. A line is used only to establish the starting position (spaced at exactly 25 yards on roughly the 21-foot depth contour). Each swimmer swims to shore on a predetermined heading, making independent estimates of location and water depth.

1.1.4.2.1.2.1 Assumptions

The error in the measured beach slope for both procedures has been analyzed for a plane-parallel bathymetry with slopes of 0.02, 0.04, and 0.08. Depth measurement errors due to waves and tides, and grid errors from estimation of position using ‘kick’ counts, with and without currents, are considered. We have not included diver’s depth gauge and compass errors.

Depth Error: For wind waves with a period of 10 seconds and a height of a meter (near the breakers) and infra-gravity waves with a period of 100 seconds and a height of a meter (near the shore), we assumed that the depth error due to waves has a Gaussian distribution with a standard deviation of 0.2 m (within 0.33 m of the correct depth 90% of the time. With a 16-man platoon, a beach width of 400 yards is surveyed. We assume ten minutes are required to log depth, survey for debris and mines, and advance 25 yards onshore. Six-foot tidal cycles, with the surveys starting two hours and one hour before high tide and at hide tide, are also considered.

Grid Error: The initial error in the platoon’s cross-shore position, at the 21-foot depth contour, is governed by the wave error divided by the bottom slope. Subsequent errors are assumed due to ‘kick count’ position error with and without alongshore currents. The effects of cross-shore currents are not considered. We have made the following specific assumptions for the above two procedures:

A taut line is used throughout the survey. The line keeps the platoon properly spaced in the alongshore direction and assists in the alignment. We modeled this in two steps: 1] after each advance, each swimmer is given a random cross-shore position error with a standard deviation of 3 yards (within 5 yards of the correct position 90% of the time); 2] after the depth measurement and before advancing again, the swimmers are assumed to realign themselves. We simulate this using a linear, least-squares fit of their positions.

No line is used after the initial alignment. Although the line is discarded after being used to establish their initial spacing at exactly 25 yards, we have assumed that the swimmers remain spaced at exactly 25 yards and swim exactly perpendicular to shore. Each swimmer has a random cross-shore position error with a Gaussian distribution and a standard deviation of 3 yards (within 5 yards of the correct position 90% of the time). Unlike Case 1 above, an individual's cross-shore errors are cumulative.

To calculate the effect of the alongshore current, we used a swimming speed of 1 knot (0.5 m/s) for the time it takes to advance the 25 yards between stops (45 seconds), and we assumed that the swimmer can hold his position while surveying. However, it is noted that for a weak current of 0.1 m/s, an alongshore drift of 4.5 meters occurs in 45 seconds if the swimmer cannot see or stand on the bottom to hold position.

1.1.4.2.1.2.2 Results

Figure 1.1.4-2 shows a typical grid for parallel reconnaissance using a taut line to aid in alignment (Case 1). There are no currents. Figure 1.1.4-3 shows the additional positioning error resulting from no alignment aids (Case 2) The fundamental difference between Figures 1.1.4-2 and -3 is that the latter figure shows the cumulative error as the SEAL team moves inshore. Figure 1.1.4-4 shows the effect of a 0.1 m/s alongshore current for Case 1 (using a taut line to aid in alignment). This is a very weak, almost imperceptible current, yet the grid can be in error on the order of 50m at the shoreline. A typical contour map drawn from the simulated Case 2 survey method (no currents) is shown in Figure 1.1.4-5. Bottom roughness is primarily artifacts of swimmer cross-shore positioning error.

Table 1.1.4-3 shows the beach slope estimates subject to grid (swimmer position) error and depth (tide and wave) errors on plane, parallel beaches with slopes of 0.02, 0.04, and 0.08. In calculating the grid error, the initial error in the platoon's cross-shore position, at the 21-foot depth contour, is governed by the wave error divided by the bottom slope. Grid errors are the largest. With a plane, parallel beach, there is no error in measured beach slope resulting from an alongshore current. At low beach slope, the swimmer error benefits from a larger number of measurements. The tidal error depends upon the start time relative to high tide and the length of the survey (this survey took 2.5 hours for the lowest beach slope). At high beach slope, the tide error benefits from the short time necessary to perform the survey. The wave error is small. At low beach slope, the wave error benefits from many measurements and the large cross-shore distance from the 21-foot depth contour to shore.

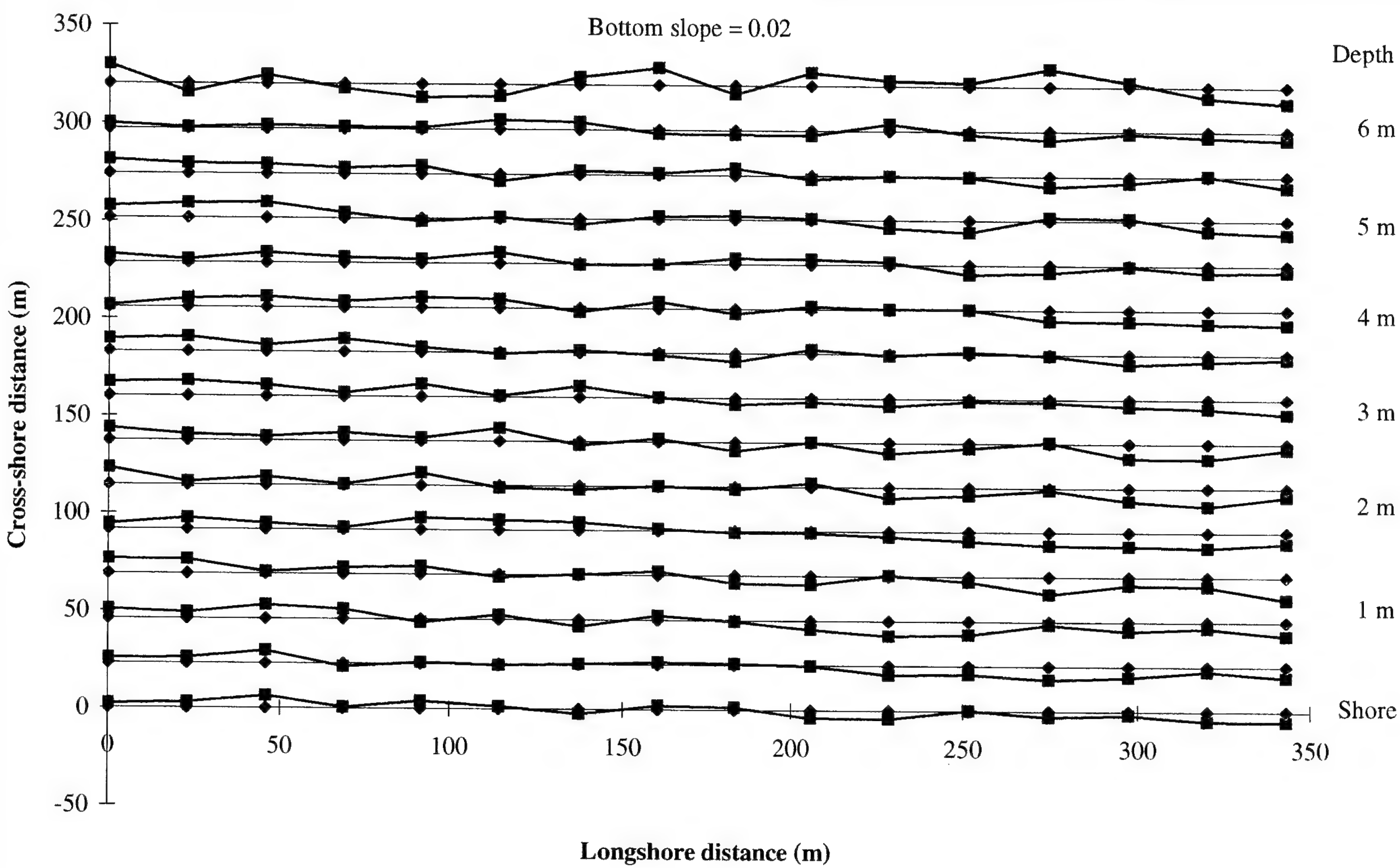


Figure 1.1.4-2. Typical grid generated with parallel reconnaissance (Case 1, no current).

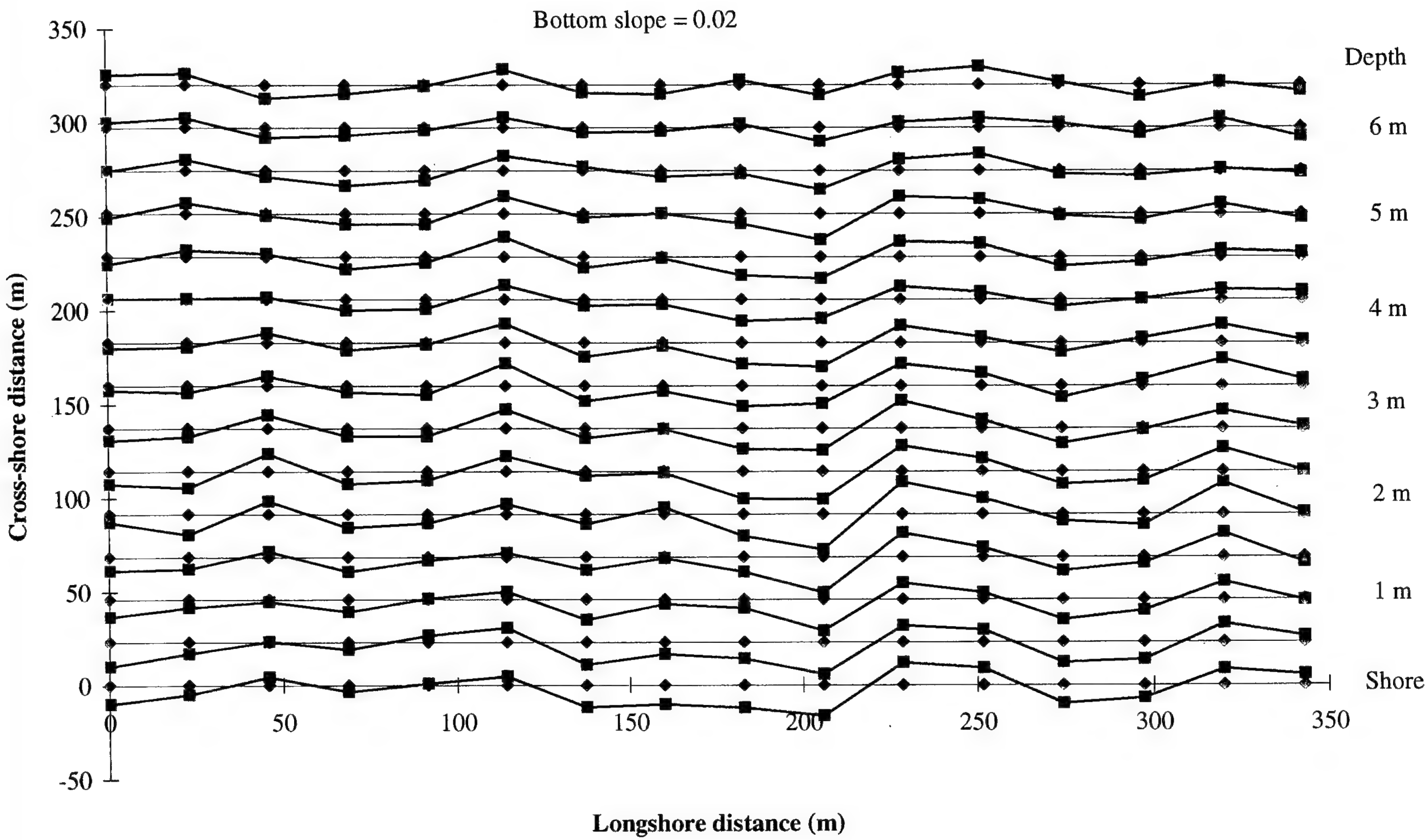


Figure 1.1.4-3. Typical grid generated with parallel reconnaissance (Case 2, no current).

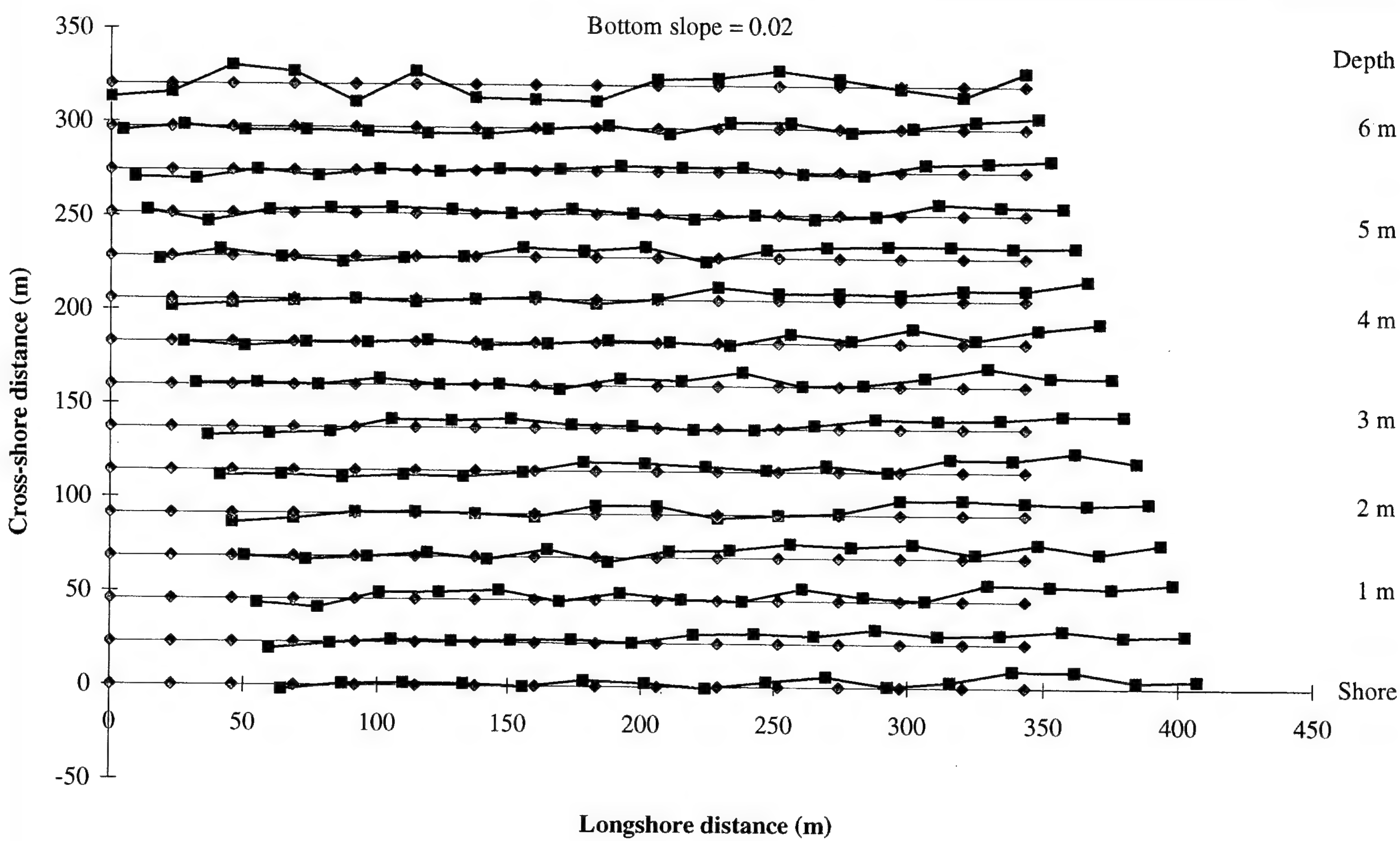


Figure 1.1.4-4. Typical grid generated with parallel reconnaissance (Case 1, longshore current of 0.1 m/s).

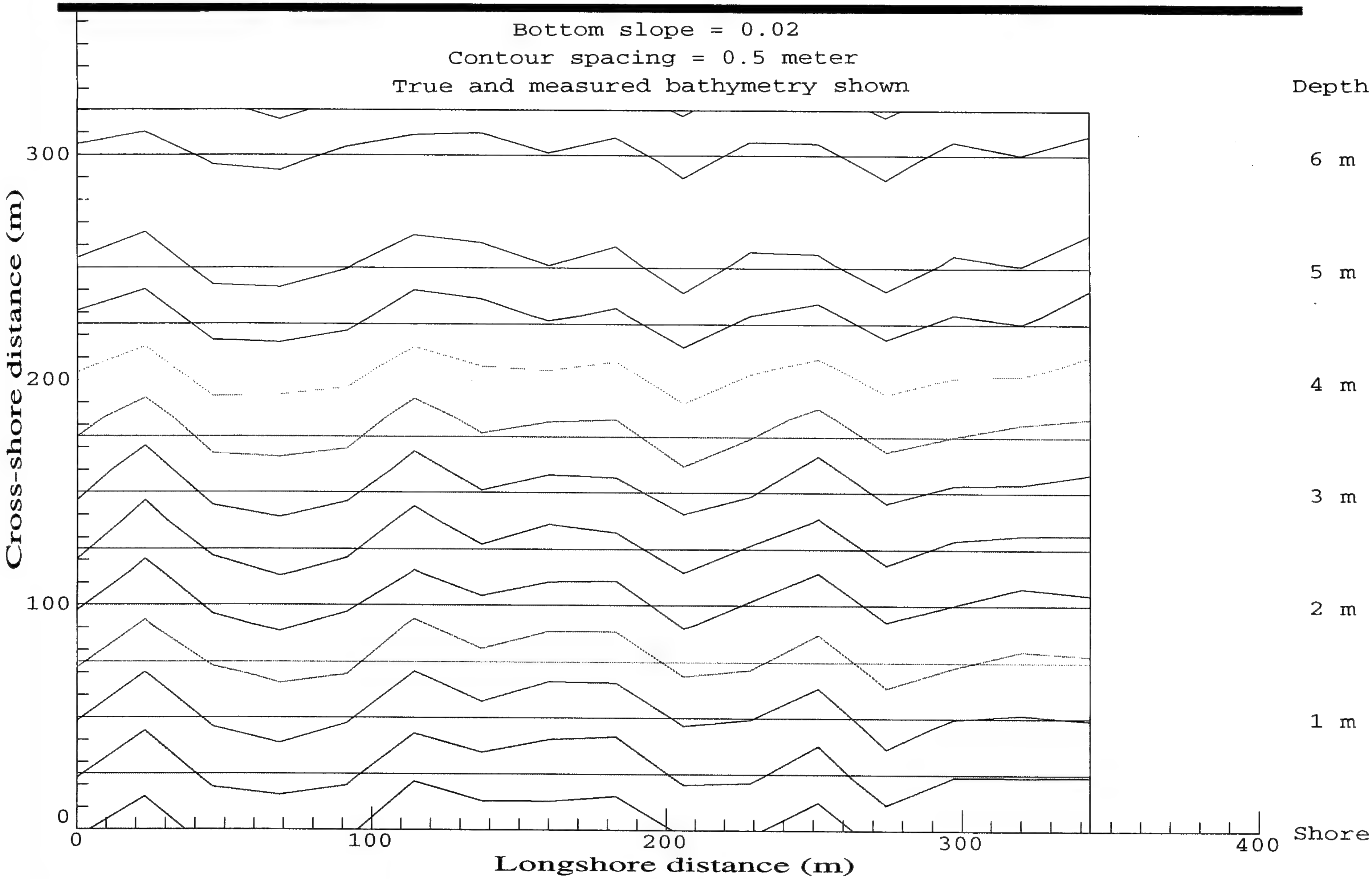


Figure 1.1.4-5. Typical bathymetry for parallel reconnaissance (Case 2, no current).

Table 1.1.4-3. SEAL team beach slope estimates for parallel reconnaissance (Case 1)

Swimming error	No tide or wave error (except initial position)	
	True beach slope	Swim error in slope
	0.02	0.00074±0.00016
	0.04	0.0022±0.0002
	0.08	0.0075±0.0007
Tidal error	**No swim or wave error**	
Start time from high tide (min.)	True beach slope	Tidal error in slope
-120	0.02	-0.0014
-60	0.02	0.0003
0	0.02	0.0019
-120	0.04	-0.0023
-120	0.08	-0.0028
Wave error	**No tide or swim error**	
	True beach slope	Wave error in slope
	0.02	0.00013
	0.04	0.00034
	0.08	0.0010

Shown below (Table 1.1.4-4) are the calculated errors due to swimmer position using a line only for initial positioning (Case 2). Errors approximately double from that for Case 1. The tidal and wave error is the same as for Case 1.

Table 1.1.4-4. SEAL team beach slope estimates for parallel reconnaissance (Case 2)

Swimming error	No tide or wave error (except initial position)	
	True beach slope	Swim error in slope
	0.02	0.0018±0.0003
	0.04	0.0040±0.0005
	0.08	0.0110±0.0013

1.1.4.2.1.3 Underwater Reconnaissance

At unsafe beaches, underwater reconnaissance is performed by one to three SEAL swimmer pairs; the number of swimmer pairs depends upon the beach width to be surveyed. The swimmer pairs spread out parallel to the beach at 50 to 200 yard intervals on the 21-foot depth contour. Their separation is the estimated beach width a pair can survey, which depends upon the estimated beach slope, the time to swim and make observations, and the maximum time that the swimmers can remain in the water. As shown in Figure 1.1-4(c), a zigzag pattern is used. Each pair swims toward shore while watching for debris and counting kicks to estimate their 25 yards, measures the water depth, and enters the data in a logbook. The time to repeat this cycle is estimated to be 2 minutes per depth measurement. When the team reaches water depths of 2 or 3 feet, they turn and swim 25 yards parallel to shore for the next measurement. The swimmers turn again and swim directly offshore, logging the depth at 25-yard intervals until they reach or pass the 21-foot depth contour. If time is available, they advance 25 yards alongshore and start a new pattern.

1.1.4.2.1.3.1 Assumptions

We have analyzed the error in measured beach slope as done for parallel reconnaissance. For a plane, parallel beach, we again considered the effects of waves, tides, currents, and swimmer positioning error. Each swimming pair has an initial positioning error related to their error in depth measurement caused by waves and the bottom slope. Thereafter, the swimmers can err in heading as well as distance between survey grid points. Swimmer heading error has been given a Gaussian distribution with a standard deviation of 3 degrees, and swimmer position error has been given a Gaussian distribution with a standard deviation of 3 yards (within 5 yards of the correct position 90% of the time). The same assumptions apply when swimming onshore, alongshore, or offshore. However, now navigation errors are cumulative. Wave, tide and current errors are handled as before.

1.1.4.2.1.3.2 Results

A typical grid, shown in Figure 1.1.4-6, illustrates the navigational errors the underwater swimmers may make with no current. For this beach slope and survey width, it is assumed that four swimmer pairs are required to survey within two hours. Figure 1.1.4-7 illustrates the effect of a 0.1 m/s alongshore current on the grid location. The 0.1 m/s current was only applied while the swimmers were in motion. A typical contour plot of the bottom topography resulting from a typical underwater reconnaissance with no currents is shown in Figure 1.1.4-8.

In Table 1.1.4-5, grid (swimmer) errors and depth (tidal/wave) errors in beach slope are shown for plane-parallel beach contours with 0.02, 0.04, and 0.08 slopes.

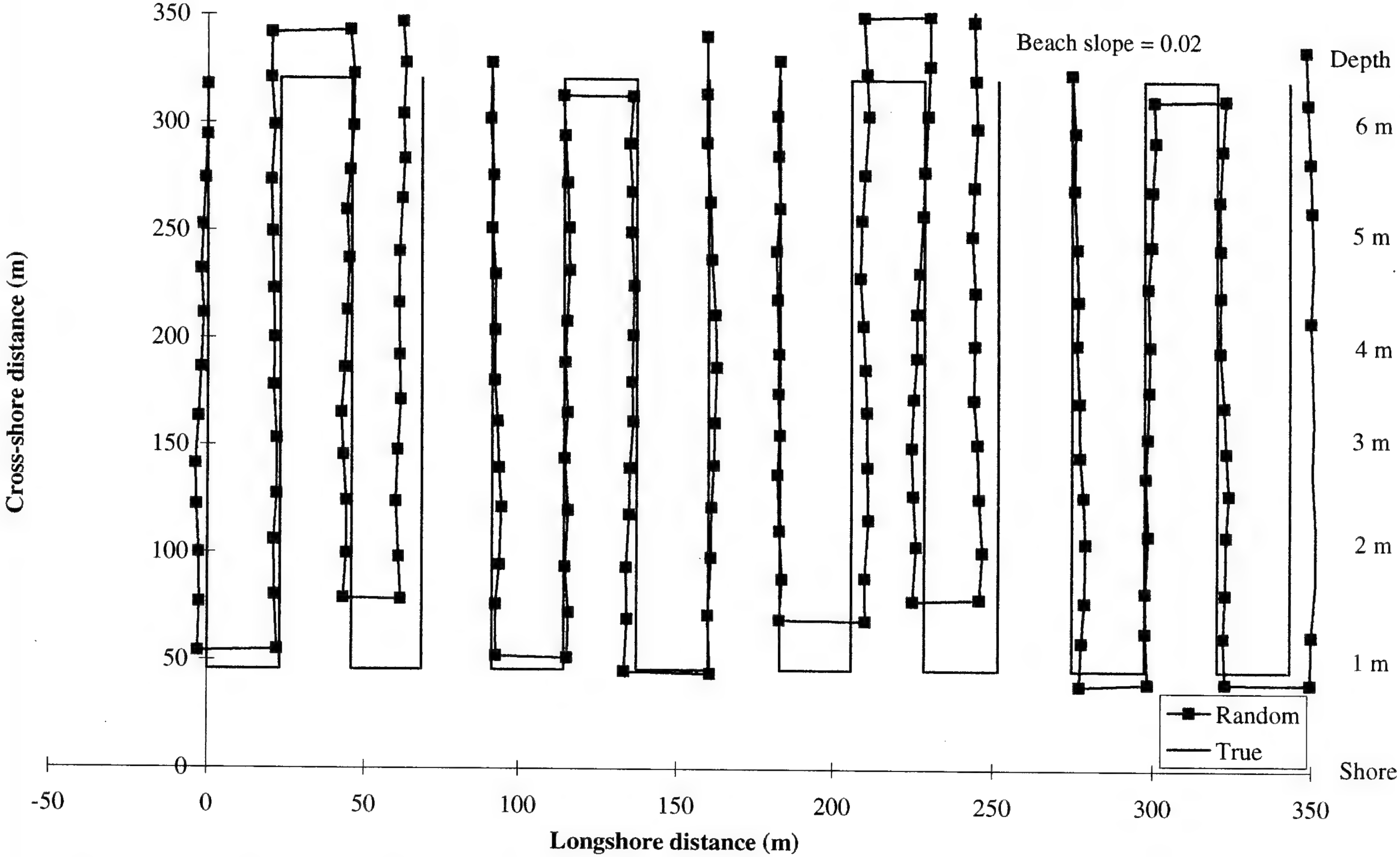


Figure 1.1.4-6. Typical grid generated with underwater reconnaissance (no current).

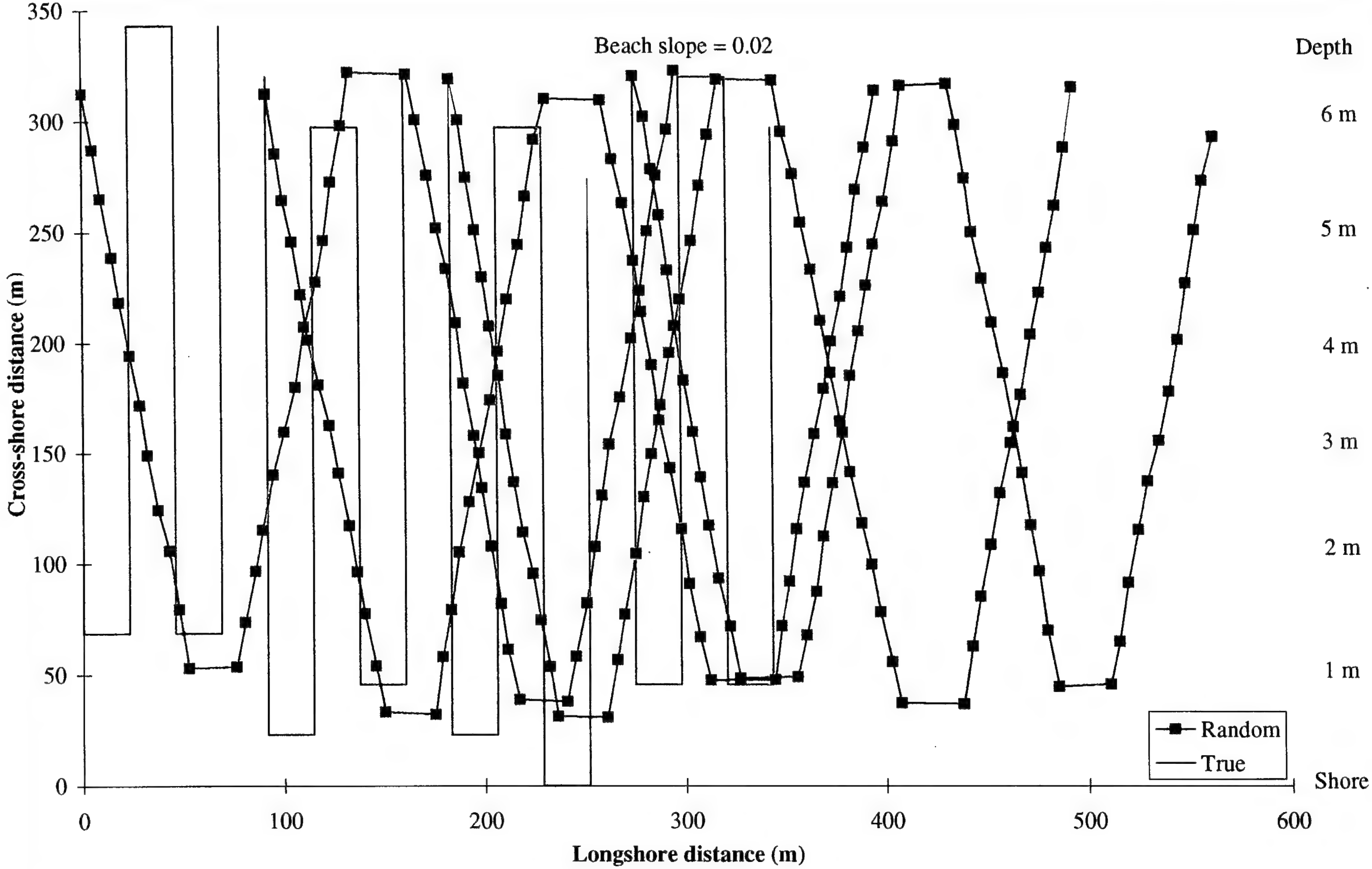


Figure 1.1.4-7. Typical grid generated with underwater reconnaissance (alongshore current of 0.1 m/s).

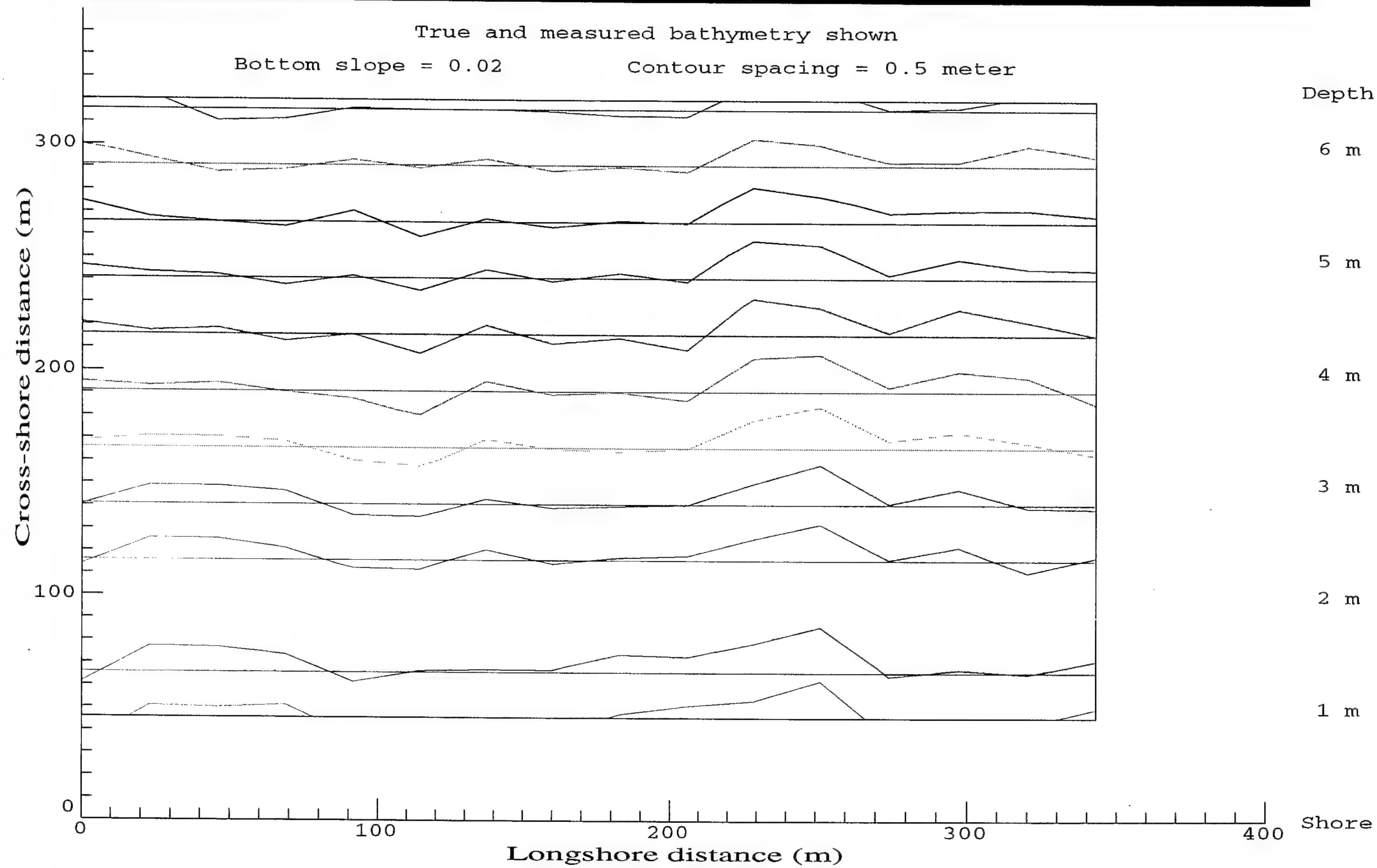


Figure 1.1.4-8. Typical bathymetry for underwater reconnaissance (no current).

Table 1.1.4-5. SEAL team beach slope estimates for underwater reconnaissance

Swimming error	**No tide or wave error (except after initial position)**	
	Beach slope	Swim error in slope
	0.02	0.0027±0.0009
	0.04	0.0076±0.0017
	0.08	0.021±0.006
Tidal error	**No swim or wave error**	
Start time from high tide (min.)	Beach slope	Tidal error in slope
-120	0.02	-0.00006
-60	0.02	-0.00008
0	0.02	-0.00007
0	0.04	-0.00004
Wave error	**No tide or swim error**	
	Beach slope	Depth measurement error in slope
	0.02	0.00016
	0.04	0.00041
	0.08	0.00098

1.2 Task 2: Field Campaign #1 - Depth Profile and Current Resolution

1.2.1 Overview

The objectives of this field campaign remain unchanged. They are:

1. collect a data set to be used to test the depth profile and current resolution of the infragravity k,f spectral inverse method, and to
2. test the automated data collection and analysis system.

Field Campaign #1 will take place during early Fall of 1998. We have selected the US Corps of Engineers Field Research Facility at Duck, NC, as the site for Field Campaign #1. This location meets all of the site requirements as listed in the October 1996 Semi-Annual report. It has additional desirable features of:

- a long pier which will facilitate logistics;
- a data collection facility that can provide collateral information to the BPS arrays (including video);
- equipment to facilitate deployment and recovery of in-water systems;
- excellent bathymetric survey capability;
- well-documented, high-resolution long-term bathymetry;
- a highly capable staff to assist us with the field operations.

We believe our use of this facility will help assure a successful first BPS Field Campaign.

In the remainder of this section, we describe the laboratory and local field tests to be conducted in the next six months (section 1.2.2) in preparation for Field Campaign #1. The concept of Field Operations for Campaign #1 is updated in section 1.2.3.

1.2.2 Testing of the BPS Sensor Package Mooring, Hardware, and Communications

This section describes the plan for the initial laboratory and in-water tests for the Sensor Package Field Tests. These tests will culminate in an ocean field test of a prototype BPS station consisting of two Sensor Packages, a Junction Box, an Onshore Array Controller, and an Onshore Processor. This test will take place in August, 1997.

We first describe the objectives, approach, and methodology for the ocean testing of this limited-element BPS Station. We then describe the testing that will precede the August ocean test.

1.2.2.1 The Objectives and Approach for the August 97 Ocean Test

1.2.2.1.1 Objectives

1. Verify the acquisition, transmittal, and recording of pressure and current data;
2. Test the suitability of the Sensor Package design and mooring methodology;
3. Verify the transfer to battery operation and internal recording when the connection to shore is broken;
4. Train the BPS team on the installation, operation, and recovery of the BPS equipment.

1.2.2.1.2 Approach

Test Site: We will execute the Sensor Package Field Tests at a location along the Washington State Pacific Coast approximately 2 km south of Copalis, WA. This site has convenient vehicle access to the beach and minimal pedestrian and vehicular beach traffic. During the test period, 18 to 22 August 97, the tidal range will be approximately 3 meters, with a low tide of nominally –0.7m in the morning and the evening.

Deployment Methodology: The equipment will be installed and recovered at low tide, thereby obviating the need for divers. The mooring posts for the array will be water-jet, using the *Rickshaw* recently fabricated for us by M.C. Clifton.

Test Duration: The tests will run a minimum of 6 hours/day for two days. The Onshore Array Controller and Onshore Processor will be monitored continuously during the test.

Equipment:

- Two Sensor Packages, each equipped with SonTek current meter, pressure sensor, clock, compass, inclinometer, batteries, and TattleTale 8. Additionally, one of the packages will be equipped with a salinity/temperature sensor clock.
- An in situ Junction Box to combine the wires from each Sensor Package into a single cable to shore.
- An Onshore Array Controller consisting of a PC computer with a multiple serial input card.
- An OnShore Processor (a P.C.) connected via ethernet to the Array Controller.
- Non-armored (SO) cable to connect the Sensor Packages to the Junction Box and the Junction Box to the Onshore Array Controller.
- Rickshaw for jetting in the offshore components.

Logistics:

- A rental truck will carry the equipment to the site.
- The onshore computers will be housed either in a tent or in a house or cabin near the shoreline.
- Electrical power for the computers will come either from the house or cabin, or we will rent a quiet electrical generator. To minimize the chance of a fuel or oil spill, the generator and fuel containers will be placed on a pan large enough to contain the volume of oil and gasoline used.
- Staging of equipment will be done either at the cabin or in the rental truck.
- We will rent a 4-wheel drive vehicle to carry the equipment to the water's edge.
- We have already obtained permissions from the local and state agencies.
- We have housing for the staff.

1.2.2.2 Field Testing of Hardware and Software Prior to the August 97 Ocean Test

This section outlines the plans for the field testing of elements of the limited-element BPS Station prior to the August Ocean Test. The schedule for these activities is given in Table 1.2-1.

Three field tests are planned:

1. Sensor Package installation methodology test
2. Pressure case integrity test
3. Sensor package functionality test

These are summarized below.

1.2.2.2.1 Sensor Package Installation Methodology Test

An initial test of the *Rickshaw* jetting system will be conducted at a sandy beach location in Puget Sound. The goals are to verify operation of the *Rickshaw*, to become familiar with its use, and to test that our installation methodology is sound. We will use it to install pipes of various diameters and lengths.

1.2.2.2.2 Pressure Case Integrity Test

Before adding electronics, we will test the pressure cases for integrity. This will be done in either of two ways: in a pressure test chamber or from a boat in Puget Sound. The test will take place at a depth of 30 m (or at an equivalent pressure) for a minimum of 30 minutes.

1.2.2.2.3 Sensor Package Functionality Test

This will be the first underwater test of a sensor package. It will be tested for independent operation (on batteries and internal recording) and for data relay through a cable to the array controller onshore. This test will be done at a local Puget Sound or Lake Washington beach.

1.2.3 Update of the Concept of Field Operations for Duck, NC Site

The Duck, NC, site selected for Field Campaign #1 has existing facilities that will simplify the field effort. Changes to the Concept of Field Operations described in section 1.2.3 of the October 1996 Semi-Annual Report are listed below.

- The Corps of Engineers' CRAB vehicle will be used to perform bathymetric surveys and to install and recover equipment.
- The onshore computer equipment will be kept inside a building rather than in a trailer or tent.

Table 1.2-1. BPS Test Schedule for Task 4 - Hardware Development and Testing

Date	Mechanical	Electronic	Software	In-Water Field Testing
4/11/97		Proto board test complete	Test of TattleTale software complete	
4/14/97		Begin board fabrication		
4/25/97	Pressure case design complete		Begin revision of TattleTale software	
4/28/97	Fabricate pressure cases		Complete revision of TattleTale software	
5/2/97		Electronic board complete		
5/5/97		Start electronic test	Test revised TattleTale software	Test of rickshaw and install techniques
5/9/97	Pressure cases complete		Test array controller software	
5/12/97	Start pressure test		Test onshore processor software	In-water pressure case testing w/o internals
5/15/97				Test of rickshaw and install techniques
5/23/97	Pressure test complete	Electronic test complete		
5/26/97	Begin fabrication			Test of first sensor package and jetting tech.
6/20/97	Fabrication complete			
6/23/97	Begin integration			
7/18/97	Integration complete			
7/21/97	Begin all-up lab test of system	Begin all-up lab test of system	Begin all-up lab test of system	
8/1/97	Complete all-up lab test of system	Complete all-up lab test of system	Complete all-up lab test of system	
8/18/97	Begin ocean field test	Begin ocean field test	Begin ocean field test	Begin ocean field test
8/22/97	Ocean field test complete	Ocean field test complete	Ocean field test complete	Ocean field test complete

1.3 Task 3: BPS Software Development and Testing

1.3.1 Overview

The focus of this task during the report period has been finalizing (1) the initial functional design of the software to be run on the various components of the BPS system, and (2) the detailed design of the software necessary for testing in August 1997 (the Sensor Package Field Tests). The status of items identified in the last semi-annual report, as work we anticipated to be done during this period, is as follows:

- The bench-test function for the Onshore Processor testing has been modified to use data collected during previous field campaigns (the Samson and Delilah campaigns at Duck) rather than generating simulated time-series data. We will revisit the use of simulated data when we extend the Onshore Processor capabilities to processing beyond the time-series files.
- The design of the processing to be implemented in the Onshore Processor up to the time-series files has been completed, and the algorithms have been tested on a development system. Work has begun on coding the software to be run in the Onshore Processor (a combination of C/C++ code and FORTRAN code) and some of the component-levels testing has been completed.
- Initial coding and testing of the software to be implemented in the Sensor Package Controllers (TattleTale 8 processors) has been completed. More details on this are presented under discussion of Task 4.
- Volumes 1 and 2 of the BPS Software Documentation have been updated as necessary throughout the period.

1.3.2 Update on the Onshore Processor and Array Controller Software Design

The functions to be implemented in the Onshore Processor and in the Array Controller (now an Intel-based PC operating onshore) for the Summer 1997 Sensor Package Field Tests are summarized in Tables 1.3-1 and 1.3-2. Note that some of the functions to be implemented in the Array Controller (denoted in Table 1.3-2 as NON-STANDARD CAPABILITIES) are backups to the Onshore Processor which are to be used only if the Onshore Processor fails for some reason (hardware or software). The in-situ Sensor Package Controllers will have all functions implemented for this testing (see section 1.4.3.2).

Messaging and time-synchronization have been modified during the period as the roles of the major components have changed. The time-synchronization function has been moved from the Onshore Processor to the Array Controller, and the method of time-synchronization (and data-collection synchronization) has been modified as well. Table 1.3-3 lists the messages that will be used to communicate data, commands, and synchronization information between the various components of the system.

Table 1.3-1. Onshore Processor Functions for Summer 1997 Sensor Package Field Tests

I. Communications
   A. Transmit messages to the Array Controller
      1. Data-collect synchronization
      2. Data-message retransmission request
      3. "Reset to program" command for a Sensor Package Controller
   B. Receive and handle messages from the Array Controller
      1. Data messages (routine and retransmissions)
      2. Time-difference messages (from Sensor Package Controllers)
      3. Data-collect synchronization messages (from Sensor Package Controllers)

II. Processing (as in Appendix C of Volume 1 of the BPS Software Documentation)
   A. Build the data-message buffer file (C.2.1)
      1. Validate message (check headers, checksums, etc.)
      2. Request retransmission if necessary
      3. Write message to the (circular) buffer file
   B. Transfer messages to the raw netCDF file (C.2.2)
   C. Run all time-series processing as in C.2.3 except deglitch processing
   D. Do *not* perform any of the full-array quality control processing (C.4)
   E. Build a log file (time-stamped ASCII entries)
      1. All messages sent/received
      2. Changes made to configuration files
      3. Problems encountered in processing (includes QC problem summaries)

III. Displays
   A. Preliminary version of the array-status display
   B. Clock (may be standard Windows/NT clock display)
   C. Data plots
      1. Plots of 2Hz time-series data
      2. Plots of power-density spectra (individual with ensemble-averages)
      3. Plots of header data and analysis results (1 sample/1024 seconds)
      4. Plots of subinterval averages and variances (4 or 8 /1024 s)
      5. Plots of PUV directional spectra (optional)
   D. Print output
      1. Info from any data-message header
      2. Non-data messages received from the other processors/controllers

Table 1.3-2. Array Controller Functions for Summer 1997 Sensor Package Field Tests

I. Communications
   A. Send date/time specification messages to Sensor Package Controllers
   B. Originate time-sync hardware interrupt to Sensor Package Controllers
      1. Access GPS (or WWV) clock to determine when to send sync.
      2. Use digital I/O (DIO) board to send hardware interrupt
   C. Receive and act on messages from the Onshore Processor
      1. Data retransmission requests
      2. Pass-through messages for the Sensor Package Controllers
         a) Data-collect sync message (broadcast to all packages)
         b) "Reset to program" (to individual package)
   D. Receive and act on messages from the Sensor Package Controllers
      1. Data messages (save for transmission to Onshore Processor)
      2. Pass-through other messages to Onshore Processor immediately
   E. Send data messages to the Onshore Processor
   F. NON-STANDARD CAPABILITIES (for field testing)
      1. Originate all messages normally done by the Onshore Processor

II. Processing
   A. Build log file of messages received/sent and other activities of interest
   B. NON-STANDARD CAPABILITIES
      1. Extract information from data message headers
         a) Do routinely after transmitting data to Onshore Processor
         b) Append to ASCII files, one file per Sensor Package
      2. Extract time-series data from data messages
         a) Do on request (for a specific package/sensor)
         b) Write to an ASCII file (for passing to another system for display)

III. Displays
   A. NON-STANDARD CAPABILITIES
      1. Print (screen/printer) header information from ASCII files
      2. Print (screen/printer) log-file entries

IV. Maintenance
   A. NON-STANDARD CAPABILITIES
   B. Copy data to archive unit (Zip drive)

V. Miscellaneous/Other
   A. Communicate with the GPS clock as necessary
   B. Other

Table 1.3-3. BPS Message List

ID	Route	OP	Message Description
A1.	SC→AC	O	Data messages
A2.	AC→OP	P	Data messages
A3.	OP→AC	O	Data-message retransmission request
A4.	AC→OP	O	Data messages (retransmissions)
B1.	AC→SC	O	Date/time specification (pre-sync)
B2.	SC→AC	O	Time-difference message (Δ at time reset)
B3.	AC→OP	P	Time-difference message (Δ at time reset) SP#N
C1.	OP→AC	O	Data-collect synchronization
C2.	AC→SC	P	Data-collect synchronization
C3.	SC→AC	O	Data-collect synchronization verification
C4.	AC→SC	P	Data-collect synchronization verification SP#N
D1.	OP→AC	O	Ping Sensor Package #N
D2.	AC→SC	P	Ping SP #N (passthrough)
D3.	SC→AC	O	Respond to ping (Sensor Package status)
D4.	AC→OP	P	Respond to ping (Sensor Package #N status)
D5.	OP→AC	O	Ping AC
D6.	AC→OP	O	Respond to ping (AC status)
E1.	OP→AC	O	Send "Reset to Program" to Sensor Package #N
E2.	AC→SC	P	Send "Reset to Program" to Sensor Package #N

Notes:

1. The component abbreviations used in this table are: OP for the Onshore Processor, AC for the Array Controller, SP for a Sensor Package, and SC for a Sensor Package Controller.
2. The third column indicates if the message originates (O) at the component or is a pass-through message (P).
3. The data messages and retransmission requests (A) are as specified in the software design specification.
4. The date/time specification (B) specifies the date and time to be loaded into the SC clocks at the next (hardware-driven) time hack. The time-difference messages are sent (1) to verify that the time was reset as directed on each SC, and (2) to provide the difference

between the SC clock and the time to which the clock was set at the time the clock was reset. These need not be sent immediately upon setting the clock, but should be sent relatively soon after. This delta-time will also be loaded into the header of the next data message (clock error).

5. The data-synchronization message (C) specifies the date and time to start a new 1024-sec data-collect interval. The SC's will send the verification upon starting the interval.
6. The "ping" messages (D) are still somewhat TBD. Initially, the individual SC's will respond with a canned "I'm Alive" message with a time stamp. In the future, we may expand this to provide a few state-of-health parameters as well (internal temp, internal humidity, etc.).
7. The reset-to-program message (E) is a software reset button.

1.4 Task 4: BPS Hardware Development and Testing

1.4.1 Overview

In the last semi-annual report, we stated we would perform the following tasks in this current six-month reporting period:

Subtask	Current Status
Complete the sensor evaluation	Done
Bench test Sensor Package components	Done
Build a Sensor Package for field testing	In progress
Update the BPS Hardware Documentation	Done

In the following sections, we address relevant results and issues that pertain to these subtasks.

1.4.2 Report on Sensor Evaluation

We have completed the sensor evaluation. Our conclusions remain the same as in the previous Semi-annual report: 1) the SonTek current meter should provide good data in the nearshore and 2) we will use the SonTek in this program. Since that report Dr. Steve Elgar of Washington State University performed a short comparison of a Marsh McBirney current sensor and of a SonTek Acoustic Current Meter. They were deployed in the Torrey Pines Beach surf zone at an elevation of 50m off the bottom in a water depth of 1 meter. The correlation of the power spectra, coherence and phase between the two data sets was excellent.

1.4.3 Hardware and Software Design

1.4.3.1 Hardware Design

The Sensor Package outline has been finalized (Figure 1.4-1) to the extent of fitting components inside the instrument shell, and computing shell wall and end cap thickness.

A working prototype version of the 6-port RS232 comm port has been completed and tested.

A working prototype version of the Analog isolator/amplifier for the Setra pressure sensor has been completed and is undergoing testing. Special attention was paid in the design to minimize the effects of temperature and noise on this amplifier.

The preliminary Sensor Package power controller design has been completed. The design allows the Sensor Package to be shore-powered with any voltage between 36 and 72 volts, to permit 100% utilization of the instrument battery pack and to allow transparent switch-over from shore-power to instrument battery power (or vice-versa). Components have been ordered and received.

1.4.3.2 Sensor Package Software Design

The core program for the Sensor Package Controller has been designed and written. Presently, the program does the following:

- Initializes all Sensor Package instruments;
- Communicates with and receives data from all Sensor Package instruments;
- Maintains a 2 Hz data-collection cycle;
- Assembles collected data into blocks with the specified format; and
- Communicates with all electronic hardware (except altimeter).

1.4.4 Array Controller Hardware Design

A significant change in the Array Controller (AC) has been made during this period. The Array Controller still communicates with each Sensor Package, integrating the data and passing on to the Onshore Processor. However, the physical package has moved onshore. This change leaves us free to develop the AC concept without the constraints of having to miniaturize and waterproof it.

The AC has been given the additional function of acting as the Time Standard for the Array. To this end, the design of the AC now comprises:

- A PC-type computer;
- an 8-port communications board;
- a digital I/O board;
- a GPS synchronized standard clock.

All of the above components have been identified, and purchasing is in progress.

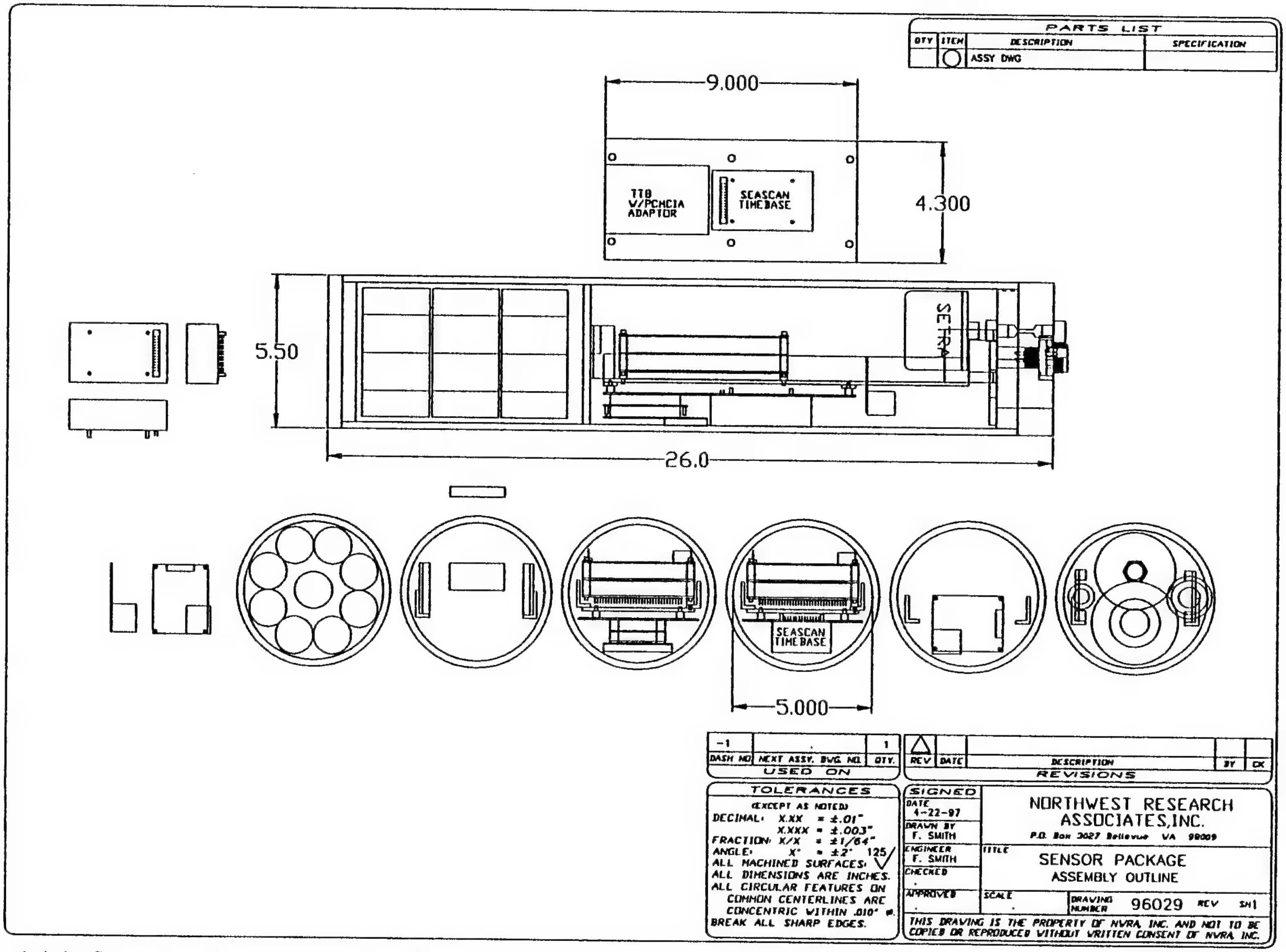


Figure 1.4-1. Sensor Package Assembly Outline.

1.4.5 Mooring System Design

The only change to the mooring system design during this reporting period is that caused by relocating the array controller to shore. The in-situ Junction Box will be moored in the same manner as was planned for the Array Controller.

1.4.6 Clocking Issues

A basic aspect of the design of the BPS system is for data collection to be synchronous at all the Sensor Packages in the BPS Array. A further mandate is that data collection continue to be synchronous even if the electrical connection between the AC and one or more Sensor Packages is lost.

Left on their own, each Sensor Package derives its time from the crystal oscillator that is part of the imbedded TattleTale 8 processor (the Sensor Package Controller). After examining the specifications of the crystal frequency stability, we found that no stand-alone crystal was sufficiently stable to allow the synchronous operation of all the Sensor Packages for one to two days. An auxiliary frequency or time standard was required.

Our solution now calls for an additional module to be added to the Sensor Package: a stabilized oscillator a SeaScan timebase/PLL. The output of this unit, suitably multiplied to the correct frequency, replaces the crystal on the TattleTale 8 imbedded processor and allows synchronous, autonomous operation of each of the Sensor Packages. This more precise clock was recommended by Mr. Mike Kirk at the Scripps Institute of Oceanography. Dave Willoughby, also at Scripps, has provided us with the details of the frequency multiplier they previously have used.

The Seascan timebase/PLL has a long-term accuracy of 5×10^{-8}. This translates to:

- 0.05 msec/17.066 min data record;
- 4.3 msec/day;
- 13 msecm/3 days;
- 91 msec/21 days.

1.5 Meetings, Reports, and Collaborations

1.5.1 Overview

An additional component of the BPS project is the communication of its activities to others through meetings and reports. These activities not only serve to provide a check on the project at all levels of experience (e.g., 6.1 through 6.4), but also to open up opportunities for collaboration, to promote synergy. It is recognized that BPS collects nearshore data that would serve nicely as background or ground-truth data for other studies. In addition, the BPS concept should not be developed in isolation of other coastal surveillance systems. The complexity of the coastal environment demands an integrated data-acquisition and analysis approach. For instance, the BPS information could enhance the resolution and confidence of remote surveillance systems as well as for wave generation/propagation models that run from blue water to the shore.

1.5.2 Advisory Panel Meeting - Nov 1996

An Advisory Panel was set up to advise throughout the life of the BPS project. Members of the Advisory Panel are:

Barry Blumenthal*	Office of Naval Research
Daniel (Dan) Crute	Coastal Systems Station
Robert (Bob) Guza	Scripps Inst. of Oceanogr.
Robert (Rob) Holman	Oregon State Univ.
Edward (Ed) Thornton*	Naval Postgraduate School
C. Linwood Vincent	Army Corps' Coastal Engineering Research Center

The first meeting was held on 14 November 1996. Attendance was excellent (only the above members with asterisks were unable to attend). This full day meeting was held at the NWRA facilities in Bellevue, WA. The itinerary of the meeting is provided in Appendix B followed by a summary of points discussed (Appendix C).

1.5.3 Washington DC Trip - Jan 1997

Joan Oltman-Shay (JOS) traveled to DC the last week in January to meet with the ONR program manager, Dr. Tom Kinder, and several members of the Advisory Panel [Drs. C. Linwood Vincent (CERC, ONR) and Barry Blumenthal (ONR)]. The main topic discussed was how to define a criterion of success for the BPS project. The result of this meeting and subsequent follow-up is the preliminary study, Defining BPS Criteria of Success (section 1.1.4).

In addition to the above meetings, JOS met with Dr. Eric Hartwig (NRL) to discuss potential NRL collaborations. This meeting resulted in JOS being invited to give a brief at NRL-Stennis on the BPS (section 1.5.5).

JOS also gave informational briefings of the BPS project to Drs. Dennis Trizna, Mel Briscoe, Keith Ward, Steve Ramberg, Doug Todoroff, and Frank Herr (all of ONR).

Dr. Trizna voiced interest in the Concept-Testing software that is being developed at NWRA model testing. He is using both NUWSAR and X-band to map surface gravity waves. Our software would enable him to model the infragravity and wind wave field. Because the software will have a Java GUI interface, it will be useable over the net. We plan to keep Dr. Trizna abreast of the progress on this suite of codes.

1.5.4 The Tactical Oceanography Symposium Meeting - Feb 1997

Dr. Oltman-Shay was asked to attend a meeting of operational Naval personnel and coastal oceanographers, brought together by NO96, ONR, and NRC to discuss issues in Naval Special Warfare. This meeting was timely for the BPS project; a criterion of success for the project could only be developed with the knowledge of other environmental surveillance methods, in particular, how the SEAL teams execute their hydrographic surveys. The material presented in this report on SEAL Team Hydrographic Reconnaissance Analysis (section 1.1.4.2.1) was acquired at this meeting.

1.5.5 NRL-Stennis Meeting - Mar 1997

Dr. Oltman-Shay was invited to give a brief at NRL-Stennis on the BPS project to a community of coastal oceanographers (organized by Todd Holland) and to meet with a group of scientists working on a new program, "Dynamically Constrained Nowcasting of Near Coastal Waves and Bathymetry," headed by James Kaihatu.

Dr. Cheryl Ann Blain voiced interest in the Concept-Testing software being developed at NWRA. She is interested in hydrodynamic modeling of the surf zone. Our software would allow her to model the infragravity and wind wave field incident to the beach. Because the software will have a Java GUI interface, it will be useable over the net. We plan to keep Dr. Blain abreast of the progress on this code.

Dr. Holland was interested in our study of the SEAL hydrographic surveys. We will keep him updated.

Dr. Rick Allard requested that we continue to keep him informed about the project. He is involved with transitioning modeling code to the Master Environmental Library for operational use.

As a follow-on to the meeting with the "Dynamically Constrained Nowcasting of Near Coastal Waves and Bathymetry" project (under Dr. Kaihatu), Drs. Oltman-Shay and Putrevu will be meeting in Delaware (late April 1997) with this group and with Drs. Rob Holman, Frank Herr, Linwood Vincent, Jim Kirby, and others.

2.0 ANTICIPATED WORK DURING 1 APRIL 1997 - 30 SEPT 1997

2.1 Task 1: Concepts and Algorithm Development

- Continue the testing of the Template Matching Technique (inverse method for a plane beach solution.
  - ⇒ Investigate, using simulated data, uniqueness, stability, and resolution of the beach slope estimates for both planar and nonplanar bathymetry.
  - ⇒ Study the effect of array geometry on the solution.
  - ⇒ Test the technique using archival field data.
- Compare the edge wave analytic perturbation expansion solution against numerical solutions, investigating issues such as the effect of the choice of the zeroth order beach slope on the first order correction.
- Study the magnitude and nature of deviations from a plane beach solution of both the edge wave dispersion and cross-shore structure solutions for various natural depth profiles and for a range of offshore measurement locations.
- Design an inverse solution for the 1st order correction to the plane beach approximation.
- Design the array geometry and offshore placement for Field Campaign #1
- Complete the design phase of the concept testing GUI (which consists of a GUI, batch processing script, and conflicts-executive); start implementation in code.
- Update the BPS Concept Testing Software Documentation.

2.2 Task 2: Field Campaign #1 - Depth Profile and Current Resolution

- Complete logistics preparation for the Sensor Package Field Test.
- Perform an ocean test of a limited-element Sensor-package BPS Station complete with Onshore Array Controller and Onshore Processor.
- Set up visit to Duck NC to coordinate with the FRF staff for Field Campaign #1 and obtain logistic information (lodging and transport).

2.3 Task 3: BPS Software Development and Testing

- Complete code implementation for the Sensor Package Field Tests (full implementation on the Sensor Package Controllers, partial implementations on the Array Controller and Onshore Processor).
- Participate in Sensor Package Field Tests. Modify code implementation and design as indicated by results of these tests.
- Begin detailed design of processing and database files in the Onshore Processor for data analysis beyond the time-series files.
- Update Volumes 1 and 2 of the BPS Software Documentation, and create a Volume 3 to cover description of the software implemented in the Array Controller (move sections from Volumes 1 and 2 which discuss the Array Controller software).

2.4 Task 4: BPS Hardware Development and Testing

- Receive and test the *Rickshaw* jetting system.
- Build two Sensor Packages, one Onshore Array Controller, and one Junction Box).
- Integrate the Sensor Package hardware and software.
- Perform bench tests and in-water tests of the Sensor Packages and Array Controller.
- Update Volume 1 of the BPS Hardware Documentation.

APPENDIX A.

Influence Functions for Edge Wave Propagation Over a Nonplanar Bottom Bathymetry

by

Uday Putrevu

and

Joan Oltman-Shay

Influence Functions for Edge Wave Propagation Over a Nonplanar Bottom Bathymetry

Uday Putrevu and Joan Oltman-Shay

NorthWest Research Associates, P.O. Box 3027, Bellevue, WA 98009

(April 22, 1997)

Abstract

The problem of edge waves propagating over a nonplanar bottom bathymetry is examined. Assuming that the variation from the planar case is small, we examine the problem using a perturbation expansion. This assumption allows an analytical estimate of how non-planar features change the frequency and spatial structure of an edge wave with a given wavenumber. We find that these changes can be conveniently expressed in terms of "influence functions." For example, the change in frequency, $\sigma_{1,n}$, of a given edge-wave mode, n, can be expressed as $\sigma_{1,n}/\sigma_{0,n} = \int_0^\infty h_1 I_\sigma dx$ where x is the cross-shore coordinate, $h_1(x)$ is the deviation from the planar topography, $\sigma_{0,n}$ is the frequency of the edge wave on a plane beach, and I_σ is the influence function. Similar results are also derived for the spatial structure of the edge wave. The results show that 1) in general, the spatial structure of the edge wave is more sensitive to bottom perturbations than the frequency, and 2) at a given wavenumber, the higher modes are more sensitive to shoreline features than the lower modes.

Typeset using REVTEX

I. INTRODUCTION

Edge wave propagation over nonplanar bottom bathymetries has been investigated numerically by Holman and Bowen[1] and Kirby *et al.*[2] Holman and Bowen found that the concave beach face, common to many natural beaches, substantially influences both the dispersion relationship and the cross-shore structure of the edge waves. Kirby *et al.* investigated the behavior of edge waves propagating in the presence of alongshore-aligned sand bars and found that while the presence of the sand bars does not significantly influence the edge-wave dispersion relationship, it alters the spatial structure of the edge waves substantially.

The aim of the present work is to provide an analytical explanation of the results cited above. To do that we consider situations in which the deviations from the planar case are small. This allows us to solve the problem of edge wave propagation over a nonplanar bathymetry using a perturbation expansion. The results not only provide an analytical explanation of the numerical results cited above but also allow us to estimate the changes in the dispersion relationship and cross-shore structure of edge waves due to nonplanar topography.

This paper is organized as follows: Section 2 discusses the mathematical formulation and solution of the problem. The general results derived in section 2 are discussed for a specific example in section 3. The final section is devoted to summarizing the paper and restating the conclusions.

II. MATHEMATICAL FORMULATION

In the absence of longshore currents, the equation governing the edge-wave surface elevation, η, reads[3]

$$\frac{d}{dx}\left(h\frac{d\eta}{dx}\right) + \left(\frac{\sigma^2}{g} - k^2 h\right)\eta = 0 \tag{1}$$

where h is the water depth, σ is the frequency of the edge wave, and k is its wavenumber. The boundary conditions associated with (1) are

$$\eta \quad \text{finite at } x = 0 \ (h = 0); \qquad \eta \to 0, x \to \infty \tag{2}$$

(1) subject to (2) is an eigenvalue problem and closed form solutions of the same are available for certain variations of $h(x)$ (Refs. 3, 4, 5).

Here we consider the situation in which we can represent $h(x)$ by

$$h(x) = h_0(x) + \epsilon h_1(x) \tag{3}$$

where $\epsilon \ll 1$ and the solution for edge waves propagating over $h_0(x)$ is known. We seek an answer to the question: What effect does the bottom perturbation, $h_1(x)$, have on the edge wave solution?

To answer this question, we introduce the following expansions for η and σ

$$\eta(x) = \eta_0(x) + \epsilon\eta_1(x), \qquad \sigma = \sigma_0 + \epsilon\sigma_1 \tag{4}$$

Substitution of (3) and (4) into (1) leads to the following problem at the lowest order

$$\frac{d}{dx}\left(h_0\frac{d\eta_0}{dx}\right) + \left(\frac{\sigma_0^2}{g} - k^2 h_0\right)\eta_0 = 0 \tag{5}$$

subject to

$$\eta_0 \quad \text{finite at } x = 0; \qquad \eta_0 \to 0, x \to \infty \tag{6}$$

The solution of (5) subject to (6) is known (by assumption). Nontrivial solutions for η_0 exist for specific values of $\sigma_0 = \sigma_{0,n}$ (the eigenvalues). The eigenfunctions, $\eta_0^{(n)}$, corresponding to these eigenvalues give the cross-shore structure of the edge-waves. (Each of these eigenfunctions corresponds to an edge wave mode, n.) In the particular case in which $h_0 = \beta x$ the eigenvalues and eigenfunctions are given by[3]

$$\sigma_{0,n} = \sqrt{(2n+1)gk\beta}, \quad \eta_0^{(n)} = L_n(2kx)\exp(-kx) \tag{7}$$

where L_n is the Laguerre polynomial of order n.

The changes to the frequency, $\sigma_{1,n}$, and the cross-shore structure, $\eta_1^{(n)}$, of a given mode n can be deduced by the order ϵ problem which reads

$$\frac{d}{dx}\left(h_0\frac{d\eta_1^{(n)}}{dx}\right)+\left(\frac{\sigma_{0,n}^2}{g}-k^2h_0\right)\eta_1^{(n)}=F_n(x) \tag{8}$$

subject to

$$\eta_1 \quad \text{finite at } x=0; \qquad \eta_1\to 0, x\to\infty \tag{9}$$

In the above, $F_n(x)$ is defined by

$$F_n(x)=k^2h_1\eta_0^{(n)}-\frac{d}{dx}\left(h_1\frac{d\eta_0^{(n)}}{dx}\right)-\frac{2\sigma_{0,n}\sigma_{1,n}\eta_0^{(n)}}{g} \tag{10}$$

Since (5) subject to (6) is a Sturm-Liouville problem, its eigenfunctions form a complete orthogonal set (*e.g.*, Ref. 6). Therefore, the solution for $\eta_1^{(n)}$ may be determined by expanding $\eta_1^{(n)}$ in terms of the eigenfunctions of the lowest order problem, *viz.*,

$$\eta_1^{(n)}=\sum_{m=0}^{\infty}a_m^{(n)}\eta_0^{(m)} \tag{11}$$

Substituting (11) into (8), multiplying by $\eta_0^{(l)}$ and integrating from $x=0$ to $x=\infty$ we get (after using the orthogonality condition)

$$a_m^{(n)}\frac{\left(\sigma_{0,n}^2-\sigma_{0,m}^2\right)}{g}=\int_0^\infty F_n(x)\eta_0^{(m)}\,dx \tag{12}$$

For $n\neq m$, (12) uniquely determines $a_m^{(n)}$. For $n=m$, (12) is satisfied if, and only if, the following solvability condition is satisfied

$$\int_0^\infty F_n(x)\eta_0^{(n)}\,dx=0 \tag{13}$$

Since $\sigma_{0,n}$, $\eta_0^{(n)}$, and h_1 are assumed known, (13) determines $\sigma_{1,n}$, the correction to the dispersion relationship. In particular, (12) and (13) imply that

$$\frac{\sigma_{1,n}}{\sigma_{0,n}}=\int_0^\infty h_1(x)I_\sigma(x,n)dx \tag{14}$$

$$a_m^{(n)}=\int_0^\infty h_1(x)I_x(x,m,n)dx \tag{15}$$

where

$$I_\sigma(x,n) = \left(\frac{g}{2\sigma_{0,n}^2}\right)\left[k^2\left(\eta_0^{(n)}\right)^2 + \left(\frac{d\eta_0^{(n)}}{dx}\right)^2\right]\left[\int_0^\infty \left(\eta_0^{(n)}\right)^2\,dx\right]^{-1} \tag{16}$$

$$I_x(x,m,n) = \left(\frac{g}{\sigma_{0,n}^2 - \sigma_{0,m}^2}\right)\left[k^2\eta_0^{(n)}\eta_0^{(m)} + \frac{d\eta_0^{(n)}}{dx}\frac{d\eta_0^{(m)}}{dx}\right]\left[\int_0^\infty \left(\eta_0^{(n)}\right)^2\,dx\right]^{-1} \tag{17}$$

For a given mode, n, the correction to the spatial structure is therefore given by

$$\eta_1^{(n)} = \sum_{m=0}^{\infty}{}' \, a_m^{(n)}\eta_0^{(m)}(x) \tag{18}$$

where the notation $\sum'$ means that the term $m = n$ is omitted from the summation.

Equations 14 and 15 show that the functions I_σ and I_x can be interpreted as "influence functions." These functions determine how much the bottom perturbations affect the frequency and cross-shore structure of a given edge-wave mode.

III. INFLUENCE FUNCTIONS FOR A PLANE BEACH

As an example, consider the case of depth perturbations about a plane beach, $h_0(x) = \beta x$. In this case, the lowest order solution depends only on $\xi = 2kx$ (see equation 7). Therefore, nondimensionalizing h_1 and x by $2k$ and using (7) we arrive at the nondimensional influence functions

$$I_\sigma(\xi,n) = \frac{\exp(-\xi)}{2\beta(2n+1)}\left\{L_n^2(\xi) + 2L_n'(\xi)\left[L_n'(\xi) - L_n(\xi)\right]\right\} \tag{19}$$

$$I_\xi(\xi,m,n) = \frac{\exp(-\xi)}{2\beta(m-n)}\left\{L_n(\xi)L_m(\xi) + 2L_n'(\xi)L_m'(\xi) - \left[L_n(\xi)L_m(\xi)\right]'\right\} \tag{20}$$

where a prime denotes differentiation with respect to ξ. Note that because of the nondimensionalization, equations (14) and (15) are modified to read $\sigma_{1,n}/\sigma_{0,n} = \int_0^\infty 2kh_1 I_\sigma d\xi$ and $a_m^{(n)} = \int_0^\infty 2kh_1 I_\xi d\xi$.

Equations 19 and 20 show that the magnitude of the influence functions is inversely proportional to the beach slope, suggesting that the magnitude of the effects of a given bottom perturbation, $h_1(x)$, are inversely proportional to the bottom slope. This result is a direct consequence of the fact that the relative bottom perturbation is $h_1/h_0 = h_1/\beta x$.

Figure 1 shows that the influence function for the frequency, I_σ, has its maximum at the shoreline. This implies that features near the shoreline exert the most influence on the dispersion relationship for edge waves (thus, explaining the results found by Holman and Bowen[1]). From Figure 1 we can also deduce that, at a given wavenumber, the higher modes will experience greater changes in their dispersion relationship than lower modes. This result is somewhat surprising since we would expect that because the higher modes extend farther offshore, they would be less sensitive to features very close to the shoreline. However, the numerical results of Holman and Bowen[1] [see their figure 3] also show that, in general, at a given wavenumber the higher modes experience greater changes in their dispersion relationship than the lower modes. An examination of (16) and (7) shows that the sensitivity of the higher modes to shoreline features is a direct consequence of the fact that the cross-shore derivative of $\eta_0^{(n)}$ increases rapidly with mode number.

Equation 17 shows that $I_x(x,m,n) = -I_x(x,n,m)$. Therefore, while discussing the influence function for the cross-shore structure, it suffices to restrict attentions to cases in which $m > n$. Figure 2 shows the cross-shore variation of the influence function for the cross-shore structure for a mode 0 edge wave, $I_\xi(\xi,m,0)$ [the variations for the other modes, $n = 1,2,...$ are qualitatively similar]. Figure 3 shows the variation of $I_\xi(\xi,n+1,n)$ for $n = 1,4$. Several conclusions can be drawn from these figures. First, in all cases I_ξ has its maximum value at the shoreline which suggests that the cross-shore structure of the edge-wave mode is most sensitive to features near the shoreline (*e.g.*, foreshore steepening). Second, $I_\xi(\xi,m,n)$ is the largest for m close to n which shows that the correction to the n^{th} mode edge wave surface elevation has its maximum projections in the eigenfunctions closest to n. Finally, I_ξ increases rapidly with the mode number showing that, at a given wavenumber, the sensitivity of the edge-wave cross-shore structure to shoreline features increases with mode number. This last conclusion, while somewhat surprising on first encounter, is consistent with the contributions from the cross-shore derivatives of $\eta_0^{(n)}$ and $\eta_0^{(m)}$ in (17) and the behavior of these derivatives with increasing n and m.

The functions I_σ and I_ξ determine how much an absolute bottom perturbation [or a

given $h_1(x)$] modifies the frequency and cross-shore structure of a given edge wave mode. It is also of interest to determine how much a relative bottom perturbation influences these quantities. To address this, we rewrite (14) and (15) in the following form

$$\frac{\sigma_{1,n}}{\sigma_{0,n}} = \int_0^\infty \left(\frac{h_1}{h_0}\right) I'_\sigma(\xi, n) d\xi, \quad a_m^{(n)} = \int_0^\infty \left(\frac{h_1}{h_0}\right) I'_\xi(\xi, m, n) d\xi \tag{21}$$

where

$$I'_\sigma(\xi, n) = \frac{\xi \exp(-\xi)}{2(2n+1)} \left\{ L_n^2(\xi) + 2L'_n(\xi) \left[L'_n(\xi) - L_n(\xi) \right] \right\} \tag{22}$$

$$I'_\xi(\xi, m, n) = \frac{\xi \exp(-\xi)}{2(m-n)} \left\{ L_n(\xi) L_m(\xi) + 2L'_n(\xi) L'_m(\xi) - \left[L_n(\xi) L_m(\xi) \right]' \right\} \tag{23}$$

The cross-shore variations of I'_σ and I'_ξ are plotted in Figures 4 and 5. Figure 4 shows that I'_σ reaches its absolute maximum close to the shoreline [at $\xi \sim 1/(n+1)$]. In addition to the primary peak located close to the shoreline, the higher modes exhibit secondary peaks that are smaller but broader than the primary peak. (There are $n+1$ peaks for a mode n edge wave.) The cross-shore variation of I'_ξ for a mode 0 edge wave is shown in Figure 5. This function reaches its maximum closer to the shoreline than I'_σ.

Maximization of the integrals (21) leads to the conclusion that for the class of bottom perturbations in which h_1/h_0 is finite everywhere (which excludes consideration of features like a concave beach face where h_1/h_0 becomes infinite at the shoreline), the maximum changes in frequency and spatial structure occur for cases in which $h_1/h_0 \propto I'_\sigma$ and I'_ξ, respectively. Thus, a barred profile with bar crests located at the maxima of the corresponding influence function will be the most effective in modifying the corresponding edge-wave frequency.

IV. SUMMARY AND CONCLUSIONS

In this paper we considered the propagation of edge waves over a bathymetry that deviates slightly from the case for which an analytical solution is available. Using a perturbation expansion, we derived an analytical estimate of how such deviations change the frequency and cross-shore structure of an edge wave with a given wavenumber. We showed that these changes can be conveniently expressed in terms of influence functions.

The results show that both the dispersion relationship and the cross-shore structure of the edge waves are extremely sensitive to features very close to the shoreline. The results further show that, at a given wavenumber, the sensitivity of the edge waves to shoreline features increases with mode number. We also find that, in general, the spatial structure of the edge wave is far more sensitive to the bottom perturbations than the dispersion relationship (*cf.* Figures 1 and 3). All of these features have been evident in previous numerical calculations (*e.g.*, Refs. 1, 2, 7). We have provided an analytical explanation of these numerical results.

It is also clear from the results presented here that the bottom perturbations that are most efficient in modifying the frequency of the edge wave are quite different in character from those that are most efficient in modifying the spatial structure. For example, Figures 1 and 4 show that the bottom perturbation, $h_1(x)$, that is most efficient in modifying the frequency of the edge wave will have the same sign everywhere. In contrast, Figures 2 and 5 show that the perturbation that is most efficient in modifying the spatial structure of the edge wave will not have the same sign everywhere. Thus, the choice of the base profile, $h_0(x)$, significantly affects the relative modification of the frequency and the spatial structure.

ACKNOWLEDGEMENTS

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FIGURES

FIG. 1. Cross-shore variation of $\beta I_\sigma(\xi, n)$. The numbers on the curves represent the mode number.

FIG. 2. Cross-shore variation of $\beta I_\xi(\xi, m, n)$ for $(n = 0)$. The numbers on the curves represent the values of m.

FIG. 3. Cross-shore variation of $\beta I_\xi(\xi, n+1, n)$ for $n = 1$ through 4. The numbers on the curves represent the values of n.

FIG. 4. Cross-shore variation of $I'_\sigma(\xi, n)$. The numbers on the curves represent the mode number.

FIG. 5. Cross-shore variation of $I'_\xi(\xi, m, n)$ for $n = 0$. The numbers on the curves represent the values of m.

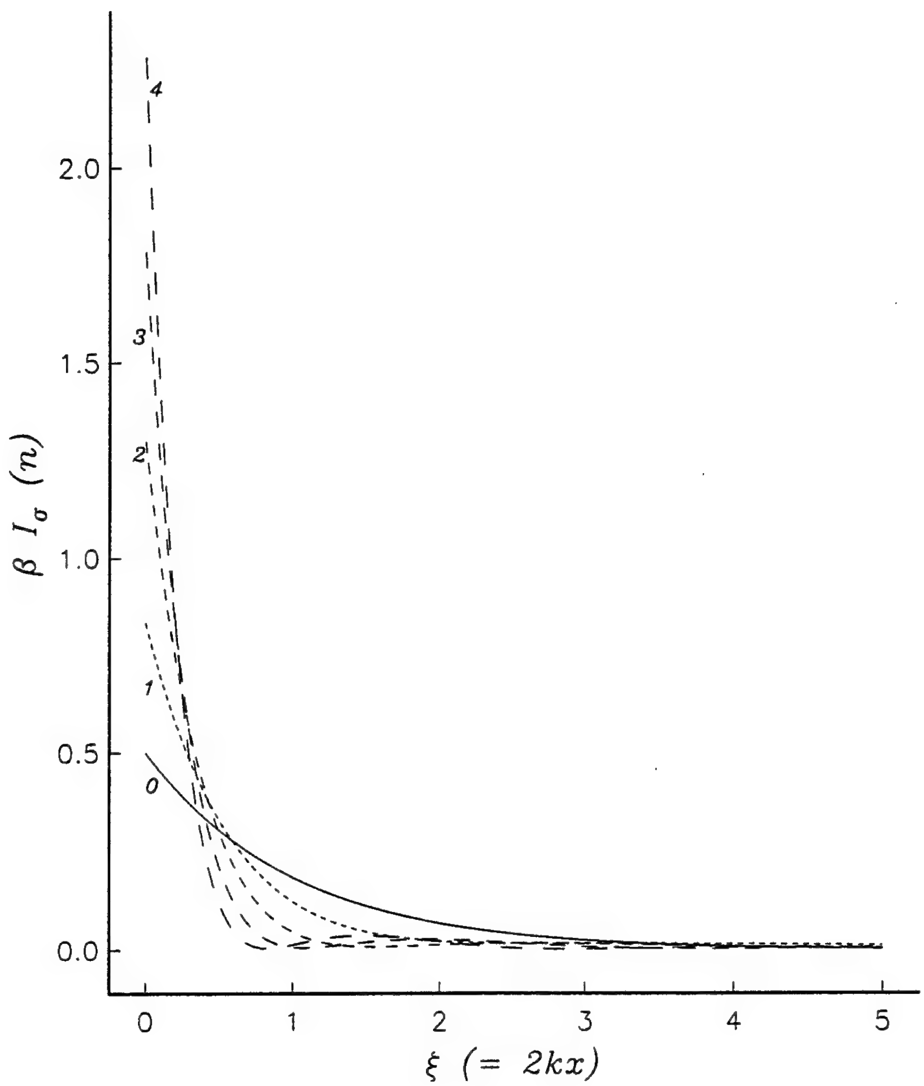

FIG. 1. Cross-shore variation of $\beta I_\sigma(\xi, n)$. The numbers on the curves represent the mode number.

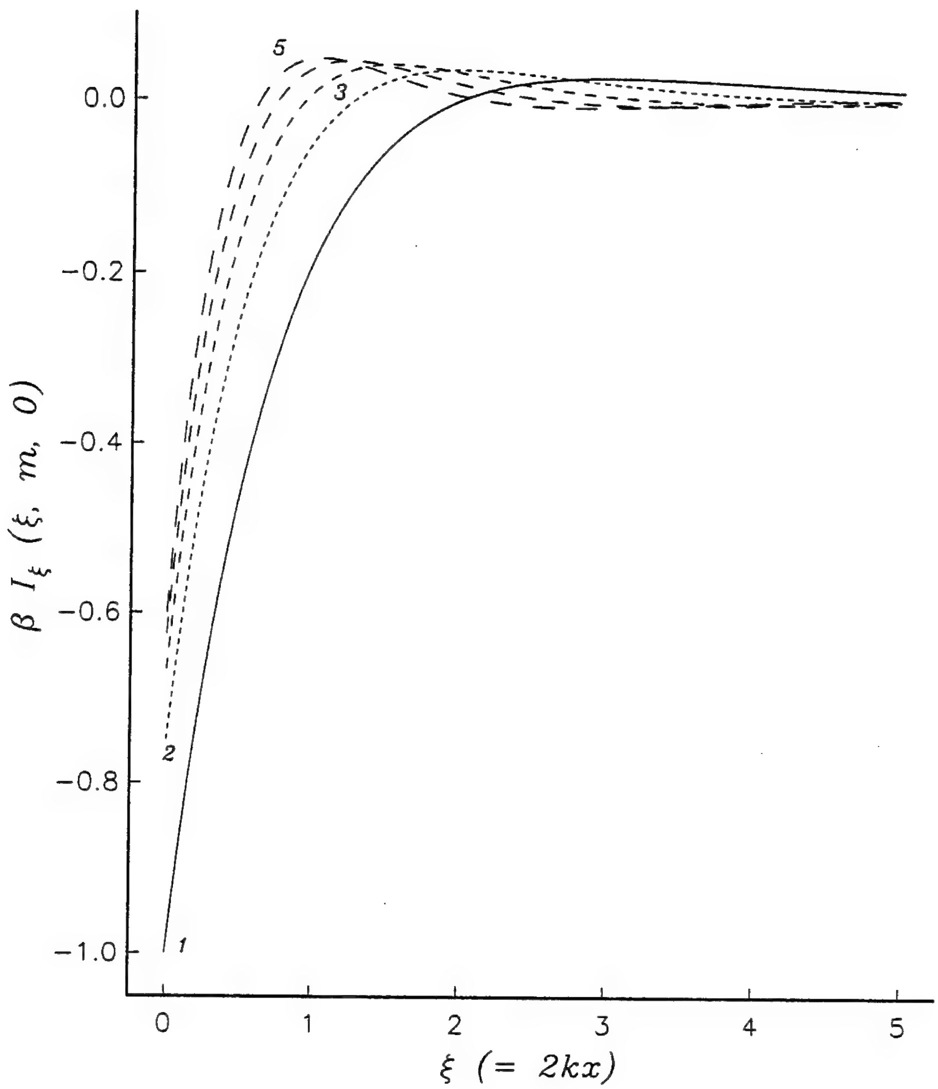

FIG. 2. Cross-shore variation of $\beta I_\xi(\xi, m, n)$ for $(n = 0)$. The numbers on the curves represent the values of m.

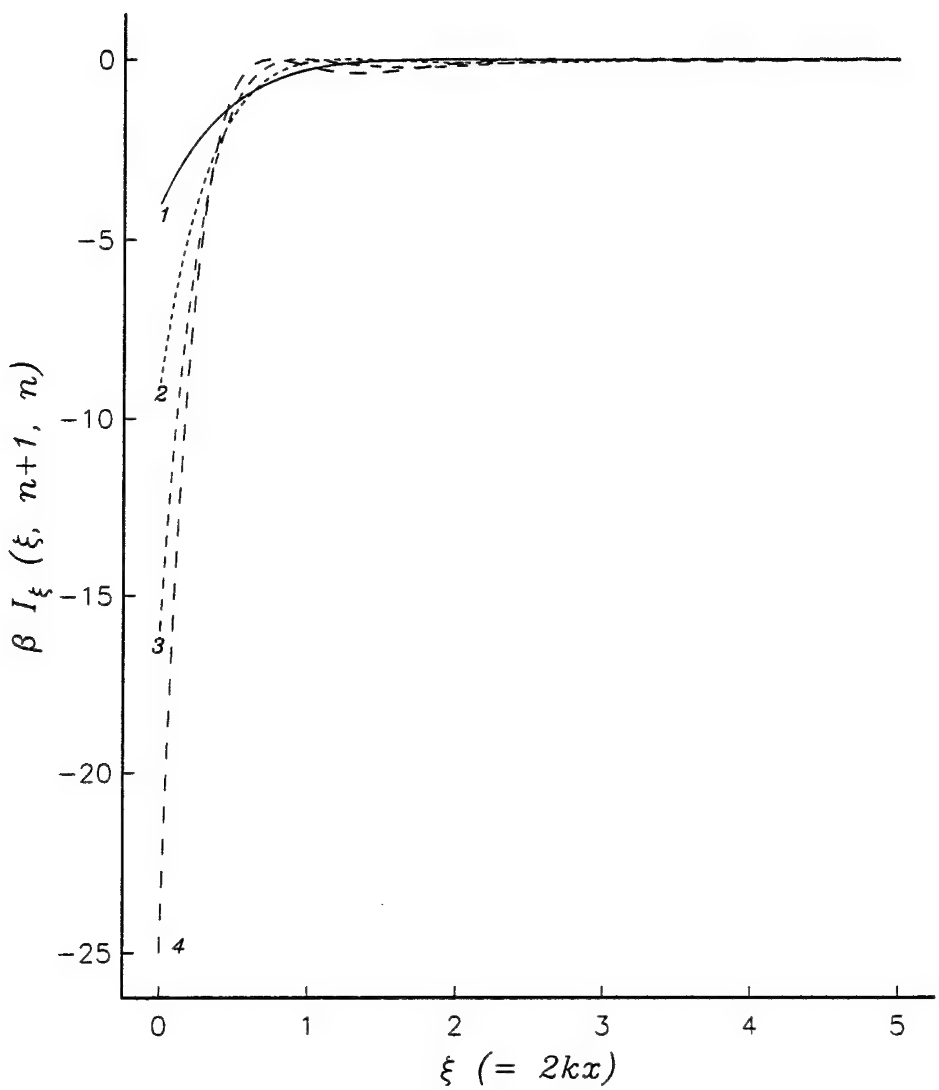

FIG. 3. Cross-shore variation of $\beta I_\xi(\xi, n+1, n)$ for $n = 1$ through 4. The numbers on the curves represent the values of n.

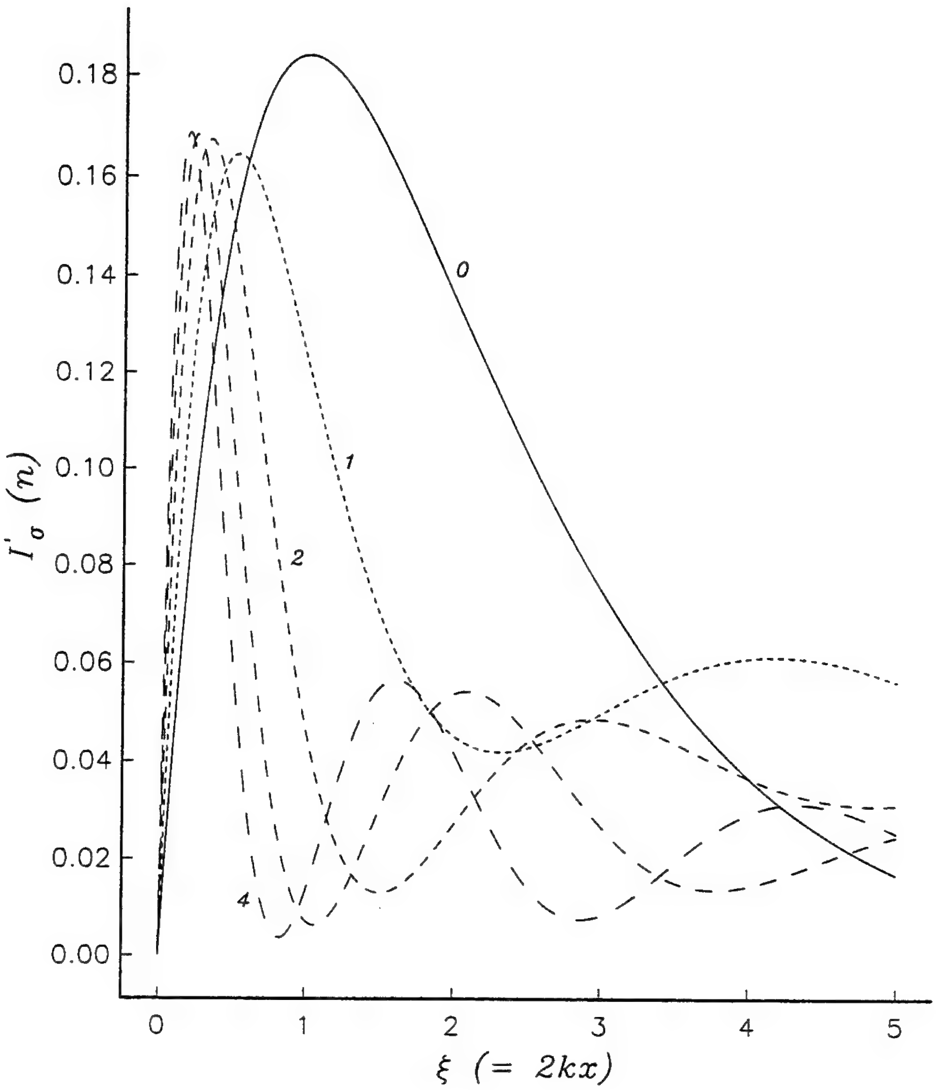

FIG. 4. Cross-shore variation of $I'_\sigma(\xi, n)$. The numbers on the curves represent the mode number.

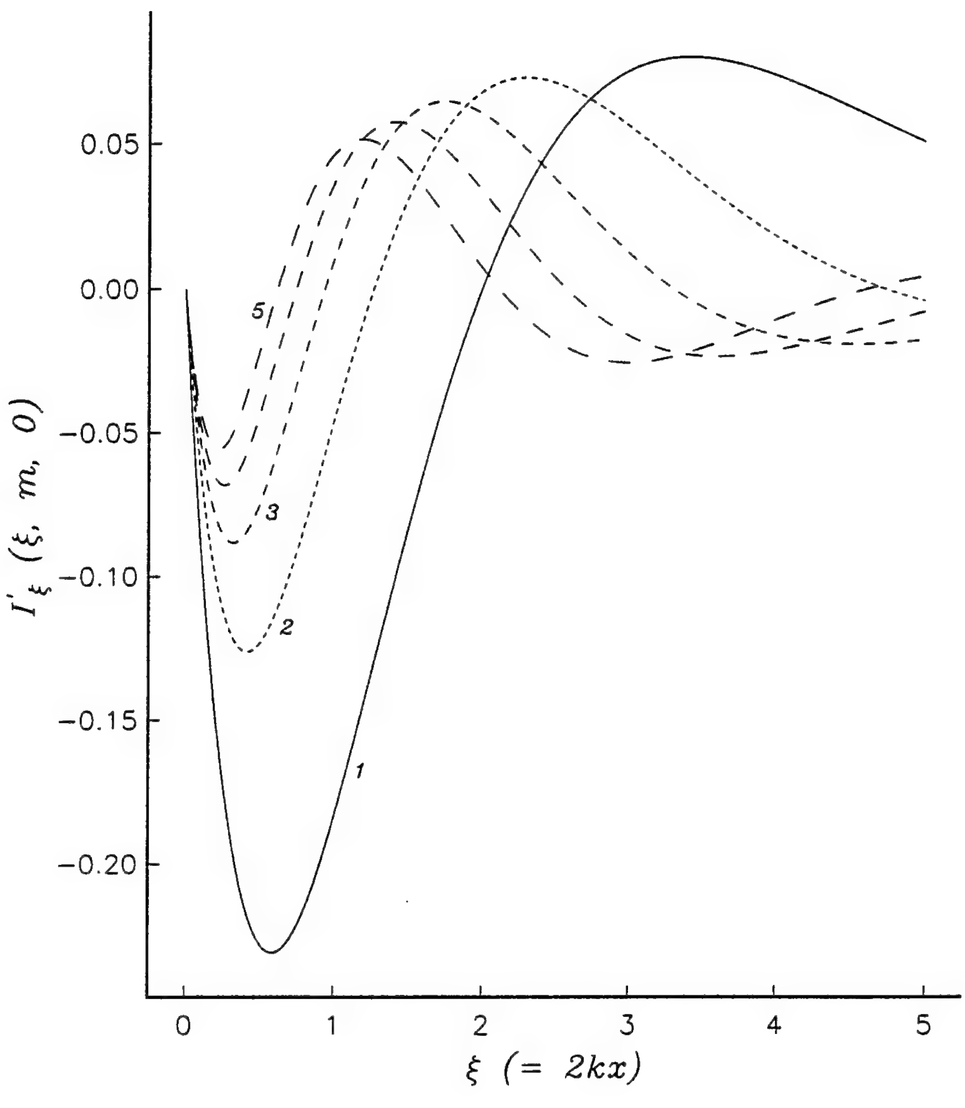

FIG. 5. Cross-shore variation of $I'_\xi(\xi, m, n)$ for $n = 0$. The numbers on the curves represent the values of m.

Appendix B.

The Advisory Panel Meeting Agenda

—14 November 96—

APPENDIX B. THE ADVISORY PANEL MEETING AGENDA - 14 NOV 96

Agenda

Time	Topic	Speaker
8:00am	NWRA Background	Ed Fremouw
8:10am	BPS Project Overview	Joan Oltman-Shay Tom Kinder
▪	Objectives and Approach	
▪	Task Organization and Schedule	
▪	Staff	
8:30am	Design, Development, and Testing of the Inverse Method	Joan Oltman-Shay
▪	Definition of the Problem/Background (pg. 11-16 of BPS Doc. #1 and pg. 2-4 of BPS Doc. #2)	
▪	Issues of Concern (Section "Stability, sensitivity, and capability testing" on pg. 22 of BPS Doc. #1 and on pg. 12-13 of BPS Doc. #2)	
▪	Tools: Concept-Testing Software (pg.10-12 of BPS Doc. #2)	
▪	Tools: Concept-Testing GUI (pg. 12 of BPS Doc. #2)	Bill Pierce
▪	[9:00am	15min BREAK]
▪	Our Present (Inverse Method) Approach (pg. 4-10 of BPS Doc. #2)	
▪	Issues of Concern	
[10:00am	15min BREAK]	
10:15am	The BPS Station Design Concept - Part 1	Joan Oltman-Shay
▪	The BPS Field Campaign Objectives and Design (pg. 33-36 of BPS Doc. #1 and pg. 13-14 of BPS Doc. #2)	
▪	BPS Sensor Package and Mooring Design (pg. 27-30 of BPS Doc. #2)	Frank Smith
▪	Hardware Issues of Concern	Skip Echert
▪	Battery and in situ data storage	
▪	SonTek current meter (pg. 23-27 of BPS Doc. #2)	
▪	Revisit Sensor Package design	
▪	SO cable versus well-logging cable	

Time	Topic	Speaker
[12:30pm	LUNCH - on site]	
1:15pm	The BPS Station Design Concept - Part 2	Jim Secan
	■ BPS Concept of Operations	
	■ BPS Software Design (pg. 16-21 of BPS Doc. #2)	
	■ Software issues of Concern	
	■ BPS GUI (QC) Demonstration	Robert Bussey
[3:00pm	15min BREAK]	
3:15pm	Other Issues	Joan Oltman-Shay
	■ FY98 Field Site Requirements and Options (pg. 14 of BPS Doc. #2)	
	■ BPS Schedule	
	■ Experiments of Opportunity	
4:15pm	Wrap Up	
	■ Open Discussion	
	■ Meeting notes	
	■ Next meeting - when and where	

BPS Documents Referenced in the Agenda

BPS Doc. #1: May 1996 Post-award revision of the technical proposal, "A Beach Probing System (BPS) for Determining Surf Zone Bathymetry....," by Oltman-Shay

BPS Doc. #2: 25 October 1996 Semi-Annual Report, "A Beach Probing System (BPS) for Determining Surf Zone Bathymetry....," by Oltman-Shay, Secan, and Echert

Displays

Hardware on table outside of conference room

Print of the full BPS Gantt chart on the wall of conference room

Appendix C.

The Advisory Panel Meeting Notes

—14 November 96—

APPENDIX C. THE ADVISORY PANEL MEETING NOTES - 14 NOV 96

Field Experiment

- Deploy Sensor Packages 50cm above the bed to ensure that the current meter remains above the sandy bed during times of significant erosion and accretion. (offered by Bob Guza)
- BPS array clock synchronization
  - ⇒ Tom Herbers (with Mike Kirk) is deploying a phase array that is too large to cable together. They have been looking into clocks. We can benefit from what they have learned. (offered by Bob Guza)
- WARNING: Bob Guza's group has had problems with one bad sensor dragging down all sensors and packages connected to it or to the same Array Controller down. (offered by Guza)
  - ⇒ SonTek Current Meters (offered by Bob Guza and Rob Holman)
  - ⇒ SonTeks are clearly a better instrument than Marsh-McBirney's. However, they have not had the rigorous field testing.
  - ⇒ There will be a number of SonTeks deployed during the Duck 97 experiment. This could provide a good field test of the instrument. (Note: Peter Howd has a long-term deployment planed for SonTeks in ~6m depth at Duck.)
  - ⇒ Some concerns are bio fouling, water wicking into cracks and crevices (i.e., at welding joints)
  - ⇒ Others using SonTeks with whom we should consult (in addition to those we have already contacted) are Guy Gelfenbaum, John Haines, Tom White, and John Trowbridge
- Data power and storage
  - ⇒ There is a lot to gain here in having in-situ data storage for relatively little money spent. The highest cost is labor and it far exceeds your extra cost of in situ data storage. (offered by Bob Guza)
- SO cable vs. Armored Cable
  - ⇒ At SIO's recent experiment at Torrey Pines, kelp entangled the cables, mounting poles were bent or pulled out. The destruction would have been the same whether they used SO or armored cable. (offered by Bob Guza)
  - ⇒ During Reggie Beach's Oregon Coast experiments earlier this year SO was used. The only cables that failed were running diagonally to the beach. However, they were not run with any strain relief wire, and they were only anchored at the end points. (offered by Reggie Beach via Frank Smith)
- Compass integrity (magnetic-field distortion concerns)
  - ⇒ We should not concern ourselves with the possibility that our electronics might generate magnetic fields that will distort the compass measurement; our problem is instead one of materials near the compass. (offered by John Booker)

⇒ Is the SonTek made of nonmagnetic material?
⇒ Are the bandits, screws, etc., nonmagnetic?

- Lightning (offered by Linwood Vincent and Bob Guza)
  ⇒ Lightning is a problem on the east coast whereas kelp is a problem on the west coast
  ⇒ The 1994 strike - every RS232 chip was selectively blasted when the lightening hit the beach
- Bathymetry measurements
  ⇒ At Duck, there is the CRAB
  ⇒ On an unsupported beach there is water with pole and boat with fathometer or Reggie Beach's wave rider with a GPS. (In Reggie's most recent field test, he was using a 2D GPS and therefore had problems with elevation error due to waves and changes in the speed of the boat. He should be getting a 3D GPS for the wave rider.)

Wave Analysis

- Template-Matching
  ⇒ An alternative to the template-matching method presented at the meeting is to transpose the f-k spectra to f2-k space and then add up energy that falls on radial lines that pass through f=k=0. One can then plot energy versus angle of the radial line to identify the observed modes and estimate the plane beach slope approximation to the true depth profile. (offered by Rob Holman).
- Alternative or Complimentary Inverse Approach
  ⇒ It may be possible to use the time of a reflected infragravity wave to travel from the array to the shore and back again as a plane beach approximation to the true depth profile. The change in tide can be used to further define the profile near the shoreline because the change in travel time will be dependent on the water elevation change and the shoreline beach slope. Use P+U and P-U of infragravity spectra to estimate travel time. (offered by Rob Holman)
  ⇒ The time travel of a reflected infragravity wave could also be used to further constrain the inverse problem, i.e., instead of minimizing roughness or h1 squared?
- Data-sample rate
  ⇒ 4 Hz is oversampling for surface gravity waves; 2Hz should be sufficient (offered by Bob Guza)
- f-ky spectral estimation
  ⇒ An alternative to the IMLE approach presented at the meeting is to use a priori information about the dispersion relation to improve estimator performance, a parametric analysis in 1D or 2D (offered by John Booker)
- Schedule
  ⇒ A first estimate of the basic capabilities of the inverse method needs to be obtained by Spring/Summer 1997 to help define the direction of the project. It is accepted that the

inverse method works in 1m depth. Is there enough unique information and is it well enough resolved in deeper water? How deep?

FY98 Experiment Site Options

- Camp Pendleton
  - ⇒ The problem of getting permissions, etc., may no longer be there; Bill Gazin, who works for Bill Hodgkiss (and used to work at Pendleton) has been instrumental in getting MPL at Scripps into Pendleton for field programs. He may be a good contact for Pendleton field site.
- Onofre
  - ⇒ It has bad access. However, it is not too public, has a 2m tide range, and is very concave
- Coronado
  - ⇒ Rob Holman might place an Argus station there for the Tactical Oceanography meeting in Feb 97. If he does, he will inform us about the observed bathymetry. Note, however, that there may be dredging of harbor in approximately 2 years w/ dumping at Coronado beach.
- Monterey
  - ⇒ Too cold for effective use of divers
- Carlsbad
  - ⇒ Often cobbly
- Duck
  - ⇒ Has the advantage of an exceptional support facility for nearshore field experiments.
  - ⇒ It was originally not considered because it often has significant bar and trough formation and is therefore not the simplest bathymetry on which to test the BPS concept. However, Rob Holman said that even Torrey Pines can have barred bathymetry. In fact, he has not yet found a beach that doesn't have bar features occasionally.
  - ⇒ It was argued that Duck could provide the variability of depth and current profiles that we really want.

Project's Measure of Success

- A measure of success is needed for this project.
- One idea: on an energetic beach with good infragravity conditions, our measure can be whether the BPS technique can do as well or better than 10 divers? → test: compare BPS with divers and ground truth → because BPS advantage is the remote sensing it need only do "well enough."
- How "well enough" is the depth profile (and other) measurement is measured by "how useful" is the information to the Navy.

Next Advisory Panel Meeting

- Panel meetings need not occur at set intervals. Instead, the meetings should be scheduled at critical technical and programmatic decision-making junctures.
- The next meeting will occur either Spring 97 or Fall 97.
  - ⇒ If in Spring 97, it will be primarily to discuss the results of the first inverse method capability study.
  - ⇒ If in Fall 97, the discussion of the inverse method would have happened satisfactorily with e-mail and snail mail, and the discussion in Fall 97 would focus on the FY98 experiment design.

Additional Questions and Answers

Linwood Vincent - How nearly plane must the beach be? Joan - the answer to that is an output of the project; by the nature of edge waves we will average the topography.

Bob Guza - Is your forward model assuming equal energy for all modes? Joan - Yes

Bob Guza - Will you add statistical noise to the edge wave forward model? Joan - yes.

Bob Guza - What fraction of the analytical work is the concept-testing GUI? Joan - it is about 6 person months. However, it will allow others to use the codes easily, so productivity is improved.